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NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

Bethesda, Md. 20034

SUMMARY REPORT ON 1971 ARCTIC TRIALS OF A 10-TON SURFACE EFFECT VEHICLE

Compiled by

J.J. Shabelski and
R. Putnam

Sponsored by

ADVANCED RESEARCH PROJECTS AGENCY
ARPA Order No. 1676
Program Code No. ON10

SYSTEMS DEVELOPMENT DEPARTMENT
RESEARCH AND DEVELOPMENT REPORT

May 1973 Report 4100

The Naval Ship Research and Development Center is a U. S. Navy center for laboratory effort directed at achieving improved sea and air vehicles. It was formed in March 1967 by merging the David Taylor Model Basin at Carderock, Maryland with the Marine Engineering Laboratory at Annapolis, Maryland.

Naval Ship Research and Development Center

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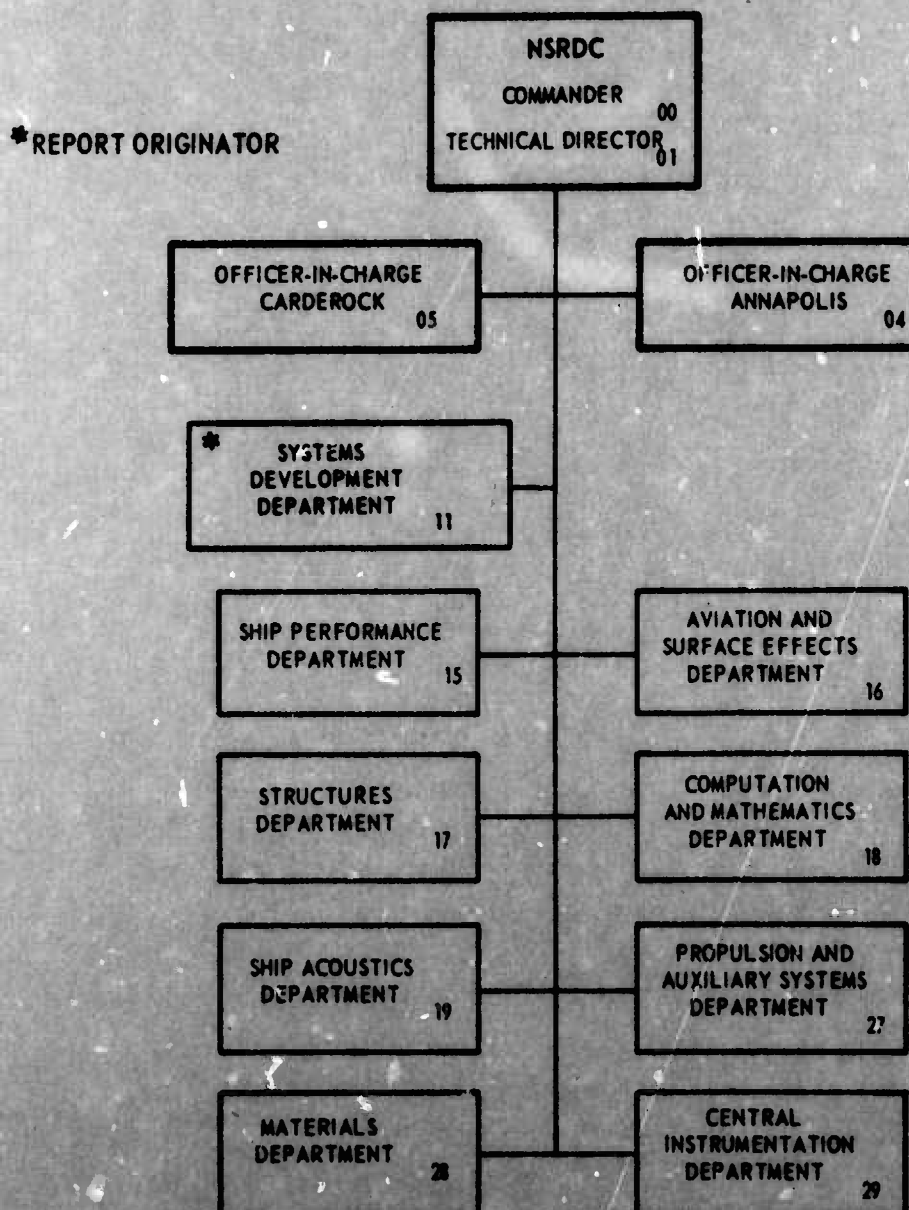

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DEPARTMENT OF THE NAVY
NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER
BETHESDA, MARYLAND 20034

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ABSTRACT

A test program for a 10-ton gross weight surface effect vehicle (SEV) was devised to document operating experience in the Arctic, to identify generic problems including limitations of SEV operation, to acquire engineering data for navigational and communication subsystems, and to evaluate environmental and ecological aspects of SEV operation. This report presents sample quantitative and qualitative results of the various tests conducted at Alameda Naval Air Station, California, and the Naval Arctic Research Laboratory at Point Barrow, Alaska, between 1 February and 28 August 1971. Detailed technical discussions are contained in cited references. An operational log and maintenance history are also presented along with pertinent observation and comments.

ADMINISTRATIVE INFORMATION

The Arctic Surface Effect Vehicle (ASEV) Program is sponsored and funded by the Defense Advanced Research Projects Agency (ARPA) under ARPA Orders 1676 and 1767 Work Unit 1-1130-100. The Naval Ship Research and Development Center (NSRDC) is Technical Manager of the Program. As part of the technology phase of the program NSRDC developed and conducted tests at Alameda Naval Air Station (California) and the Naval Arctic Research Laboratory (Point Barrow, Alaska) between February and August of 1971.[1]

INTRODUCTION

The principal objectives of the Arctic Surface Effect Vehicle Program are (1) development of the necessary technology for utilizing surface effect vehicles (SEV) as high-performance, all-weather Arctic-based military platforms and (2) demonstration that sufficient technology is available to design and construct SEV's up to 1000 tons (gross weight) that are capable of operating in the Arctic at speeds up to 100 knots and ranges up to 3000 nm. To accomplish the above objectives, the program has been separated into a two-phase effort. The first phase—technology development—is concerned with the development and validation of the designs and subsystem concepts through analytical studies, controlled laboratory experiments, and full scale field trials. The 1971 Arctic Test Program of the Arctic SEV Program Office was in support of this technology effort.

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[1] Naval Ship Research and Development Center, "Arctic Surface Effect Vehicle Program SK-5 Test Program," Arctic SEV Program Office, System Development Department (Mar 1971). A complete list of references is given on pages 132-134

The test program began on 1 February 1971 at Alameda Naval Air Station, California, and was completed on 28 August 1971 at the Naval Arctic Research Laboratory (NARL), Point Barrow, Alaska. Personnel from the Cold Regions Research and Engineering Laboratory (CRREL) of the U.S. Army, the Applied Physics Laboratory of Johns Hopkins University (APL/JHU), the Aerospace Corporation, and the Air Cushion Vehicle Evaluation Unit of the U.S. Coast Guard collaborated with NSRDC in this test program. The responsibilities and duties of the participating organizations are outlined in Appendix A.

The test craft was a refurbished and winterized SRN-5-type air cushion vehicle (ACV) that had been modified into an SK-5 by the Bell Aerospace Company. This particular craft had been refurbished by Bell for two tours of duty in Vietnam. Its salient features are outlined in the following section of this report, and the specific details of the refurbishment and winterization are given in Appendix B.

TEST FACILITIES

This section will familiarize readers with the test craft, the data acquisition system, and the test areas associated with the ARPA 1971 Arctic Test Program. Pertinent comments related to overall logistic support are also included.

TEST CRAFT

The test craft was an SK-5, originally built by British Hovercraft Corporation as SRN-5, Serial 015. It was subsequently modified into an SK-5 by the Bell Aerospace Corporation (designated as Navy Serial 002 and Coast Guard Serial 003). It originally was used as a gunboat in Vietnam and carried 15 passengers or an equivalent payload. It is powered by a General Electric (Model 7LM100-P0101) gas turbine which drives a variable-pitch propeller and a centrifugal lift fan. (This fan discharges air through a plenum chamber into a cushion system consisting of a 4-ft-high peripheral skirt with fingers and lateral and longitudinal stability skirts.) Figure 1 shows the test craft in operation; its sailient features and characteristics are listed in Table 1.

The forward speed of the test craft is controlled by varying the propeller pitch, and the hover height is controlled by varying the speed of the power turbine which is connected to the lift fan through a gearbox. Variable incidence elevators and a fuel ballast system provide longitudinal pitch trim. Directional control of the test craft is provided by twin rudders in the propeller slipstream, by puff ports which bleed air selectively from the plenum, and by the peripheral skirt which can be lifted independently at two points on each side by means of an hydraulic jack system.

The craft was refurbished and winterized (Appendix B) before being air transported to Alaska. Briefly, these modifications included:

1. Installation of heaters in the cabin and ducts to carry the heated air to defrost the forward windshield, quarter windows, and door window.

2. Installation of a small duct to force warm cabin air into the engine compartment to preheat the engine and lubricating oil.

3. Installation of aluminum fairing over the landing pads to form a closed ski-type configuration.

4. Installation of ducting from the air engine intakes to the skirt plenum.

5. Installation of an auxiliary power unit (6-kw diesel generator set).

6. Installation of an engine forward inlet seal.

In addition, the craft was provided with a radio equipped to operate on standard marine frequencies (152-157 MHz). The standard communication equipment is indicated on page 273 of the Bell manual.[2] This radio provided communication between the test craft and another marine band radio located at NARL. Hand-held walkie-talkies were utilized for communication between the test craft and the on-site test party.

DATA ACQUISITION SYSTEM

The data acquisition system (Figure 2) gathered various data inputs from transducers onto magnetic tape through a set of voltage-controlled oscillators which are part of a FM/FM proportional bandwidth multiplexing system.[3] Typical data inputs that were monitored include craft accelerations, craft structural strains, plenum pressures, plenum temperatures, test craft control functions, craft velocity, and terrain height. The system included a signal-monitoring section to provide (on-site) a permanent record of six individual data functions simultaneously.

Except for the transducers (end devices) and junction boxes, all system electronics were mounted in two standard racks. Figure 3 shows the location of the data acquisition system on the test craft, Figure 4 indicates the layout of the electronic racks, Figure 5 gives transducer locations,[4] and Figure 6 is a block diagram of the system. Each block at the top of the diagram in Figure 6 is typical for a particular type of transducer and also indicates the quantity of each type utilized. Twelve of the listed accelerometers were used to monitor craft accelerations at various locations. During some of the initial tests, five of these accelerometers were temporary, hence the notation on the block diagram "12 of 17 location."

Signal conditioning provided for transducer balancing, transducer calibration, and distribution of d-c power from power supplies A, B, and C to strain, pressure, puff port, skirt jack, linear motion, and temperature transducers. Transducers with calibration capability (CAL) are indicated for the signal conditioner in Figure 6.

As it emerged from the signal conditioner, each transducer signal was applied as an input voltage to a voltage-controlled oscillator (VCO). The VCO output was a frequency which was a linear function of the input

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[2] The Bell Aerospace Corporation, "Operating and Maintenance Manual – SK-5 Air Cushion Vehicle, Model 7232 (Volumes I and II)", Report 7232-954001 (Aug 1967).

[3] The John Hopkins University, "ARPA Arctic SK-5 Data Acquisition System: Electronic Instrumentation Manual," Applied Physics Laboratory Report QM72-012-1 (S2C-3-181), (Jun 1971).

[4] The John Hopkins University, "ARPA Arctic SK-5 Data Acquisition System: Installation," Applied Physics Laboratory Report QM-72-012-2 (S2C-2-306), (Jun 1971).

voltage. The sensitivity (low or high level) of each VCO was selected according to the transducer output voltage. VCO center frequencies are standard Inter-Range Instrumentation Group frequencies (Channels 8 through 13). Maximum frequency deviations were ±7.5 percent of center frequency. The VCO outputs were multiplexed together and applied to a multispeed 14-track, 1-in. tape recorder. No more than six signals were multiplexed and applied to any one tape track.

VCO calibration was provided by a calibration reference voltage, a set of voltage dividers, and a calibration switch. The calibration reference voltage was applied directly to the high level VCO's; this same reference voltage was divided by voltage dividers and then applied to the low level VCO's The calibration switch provided a gang calibration by simultaneously applying voltage from one of the VCO power supplies to all VCO calibration relays.

Other signals applied to the tape recorder included time signals (IRIG B time code) directly from a time code generator and through a VCO, a 25-kHz frequency reference, and voice annotation. The 25-kHz frequency reference was used for tape speed compensation at the data reduction center.

Signal-monitoring equipment consisted of the discriminator patch panel, discriminators, galvanometer amplifiers, and a visicorder. The patch panel provided for connection of the output signal from any tape recorder playback amplifier to any of six discriminator inputs. Normally, all six discriminator inputs that appear on the patch panel were patched together, and the common connection was patched to any desired output of the playback amplifier. This method enabled any or all VCO frequencies applied to a particular tape track to be monitored simultaneously on the discriminator output meters or visicorder.

The installed test equipment included a digital voltmeter, an audio signal generator, an electronic counter, and an oscilloscope. The voltmeter was suitable for setting the power supply voltages and the other signal levels, and the audio generator was used as a signal source for calibrating and aligning discriminators. The counter was used primarily to monitor VCO output frequencies during calibration and alignment. The oscilloscope was intended primarily for signal monitoring and general maintenance.

TEST AREAS

Two naval facilities were utilized for these trials – the Naval Air Station (NAS), Alameda, California, and the Naval Arctic Research Laboratory (NARL), Barrow, Alaska. This report will be concerned mainly with the tests conducted at Barrow, inasmuch as only limited performance, operational, and engineering tests were conducted at Alameda.

NARL[5] is a Navy-owned, research facility operated under contract by the University of Alaska. It is located east of the City of Barrow, about 6 miles south of Point Barrow, the northernmost point of the

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[5]U. S. Department of Defense, Navy Department, "Master Plan, Preliminary, Barrow, Alaska – Naval Arctic Research Laboratory," Naval Facilities Engineering Command, Northwest Division (Mar 1970).

United States (Figure 7). The facility is located on U. S. Naval Petroleum Reserve 4, a 35,000 square mile area under the direction of the Office of Naval Petroleum & Oil Shale Reserves. Oil exploration ended in 1953, and the Office of Naval Research (ONR) is now custodian of the camp.

NARL is intended primarily for the support of the Department of the Navy (especially research projects funded by ONR), but its facilities are available to all projects funded by any agency of the U. S. Government.

Housed in a new (1967–68) "megastructure" facility the central laboratory contains complete laboratory spaces, service and administration facilities, and sleeping quarters for test personnel. A machine shop, carpentry shop, dormitories, family living quarters, aircraft hangar, garages, warehouses, communication equipment, and a variety of special-purpose research facilities occupy buildings scattered throughout the camp and nearby areas. The NARL area of interest is essentially anything north of the Arctic Circle in Alaska, including the Arctic Ocean and ice thereon.

The area adjacent to NARL is the only true polar area in the state of Alaska; it is called the Arctic Coastal Plain and contains the North Slope. The terrain and climatic conditions near the Barrow area are representative of the Arctic Coastal Plain.[6] Figure 8 illustrates the location of the test areas selected as having the desired terrain characteristics.

Typical features of the terrain in these areas include: Natural and artificially drained lake basins, lake shore scarps and strands, pressure ridges, coastal lagoons, coastal scarps, coastal gravel beaches, and snow-covered ice.

The junction of the Beaufort and Chukchi Seas (Arctic Ocean) with the rugged coastline provides "ideal" conditions for the formation of typical pressure ridges. Elson Lagoon (part of the Beaufort Sea) east of NARL offers an excellent sheltered test area that is flat and relatively smooth in winter (Figure 9). However, the terrain is covered with snow 8 months of the year, and this snow blends the local relief into a flat surface similar to the "tabletop land" found in the western part of the United States.

In spring and summer, an area east of the camp offers an excellent location for evaluating the performance of a test craft over typical tundra (Figure 10). (Most of the tundra in the NARL complex and nearby Barrow area has been destroyed by pedestrian traffic.) The formation of first-year ice, the size of beach scraps, the general characteristics of variation in the terrain, etc., around Barrow, have already been reported[6] and will not be repeated here. Figure 11 shows the test craft operating over ice conditions typical of those encountered during this test program, and Figure 12 shows the NARL complex in late June. In addition to the terrain and climatic characteristics of Barrow, the logistic support available from the NARL dictated the selection of this area for the ARPA 1971 Arctic SEV Trials.[7]

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[6] Sellman, P. et al., "Investigations of Terrain and Coastal Conditions on the Arctic Alaskan Coastal Plain," Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire (Aug 1971).

[7] Anderson, E. B. and W. C. Yengst, "Development Area Survey Report Alaskan Basing," The Aerospace Corporation, Report TOR-006 (S5945)-22 (Jun 1970).

LOGISTICS

Logistic support problems are common to all large test programs regardless of where they are conducted. However, the need for long-range planning is compounded in the Arctic by long supply routes, slow and difficult communications, the general lack of good reliable ground transportation, and unpredictable weather.[1,7,8,*] These general problems will not be discussed in detail, but a few specific problems associated with the 1971 Arctic SEV Trials Program will be highlighted.

Support Personnel

NSRDC provided a test director with responsibility for day-to-day operation of the trial party as well as for coordinating, directing, and scheduling the efforts of all program participants. The test director was supported by a test group that varied from eight to 18 persons, depending on the type of test being conducted. The size of the party represented a compromise between an ideal crew for operation in unfamiliar conditions and the problems associated with their transport and support. Only one airline (Wien Consolidated Airlines) provides service to Barrow. Its schedule calls for one daily flight from Fairbanks during the winter months (September–May) and two daily flights during the summer months. Unfortunately, it is not always possible to land at Barrow every day because of weather conditions there and the lack of a ground radar facility. As stated previously, NARL essentially supplies the logistic support for all research conducted above the Arctic Circle, and its facilities become very crowded from June through mid-September. The size of the test crew proved adequate for a trial of this duration.

The test craft was operated and maintained by a detachment from the U. S. Coast Guard ACV Evaluation Unit, San Francisco, California, with advice and support of a contracted civilian operator during most of the trial period. His services proved invaluable to the technical trial personnel. He not only performed the specified engineering maneuvers required with the test craft, but also indoctrinated the Coast Guard operators on the proper technique and procedures for handling the SEV on ice and snow, and he assisted with both the routine and emergency maintenance of the test craft.

Support Equipment

Except in a few rare cases–engine and/or propeller removal–test craft maintenance required a minimum of special equipment. However, the nature and the purpose of this test program required certain ground facilities. For example, the availability of a mobile crane to assemble and dismantle the test craft as well as to lift it for engineering tests and maintenance support is definitely required for any future testing of this type.

[8] The Bell Aerospace Company, "Air Cushion Vehicle–Arctic Operations Study," Report 7415–950001 (Feb 1971).
*Also reported informally in NSRDC letter NP/3900.

A heated hangar was made available for assembly, repair, and routine maintenance of the test craft. During the early portion of the test program (late March through mid-June), simplest maintenance chores required some type of protective shelter. However, from mid-June on, it was usually possible to perform most of the routine maintenance outdoors except for a few instances when wind chill was high. This experience indicates that consideration must be given to the type and the nature of repairs that may have to be performed on any future craft designed to operate in the Arctic.

Spare Parts

Because of the experimental nature of this test program and the lack of adequate spare parts at the test site, large quantities of spare parts were air lifted with the test craft and arrangements made to air freight additional parts if required. With the exception of a few items (windshields, seats, windshield wipers, pitch control linkage), the spare parts taken with the test craft proved sufficient. When necessary, replacement parts were delivered by commercial air freight. The shipping of these small items created no special problems since all mail service to Barrow is by air. The only drawback with this service is when weather conditions prevent the aircraft from landing.

Difficulties were experienced in transporting large pieces of equipment. Commercial charter and military aircraft are limited in size and availability (as well as being expensive), and consequently considerably delays are experienced in shipping large pieces of equipment from Anchorage to remote areas such as Barrow.

Support Transportation

Small aircraft and ground support (trucks, weasels, etc.) were the main sources of transportation in and around the test area. A small aircraft (rented from NARL on a not-to-interfere basis) was convenient for route reconnaissance and photographic coverage during the trials.

NARL furnished trucks and weasels to take the test party to the selected test sites. Actually, however, the test craft proved to be the only reliable means of transporting men and equipment to and from the remote test sites.

Since the State of Alaska has restricted all tracked vehicles, etc. from the tundra during the summer (June–September) and since the use of any ground vehicle except a snowmobile is out of the question during the winter, a helicopter is considered the logical choice as an all-around, all-year support vehicle for any future test of a SEV. A helicopter can provide route reconnaissance along with photographic coverage and can transport personnel to remote test sites both for test course preparation and the conduct of tests.

OPERATIONAL EVALUATION

This section includes a summary of test craft operating days during the entire trial period (1 February through 28 August 1971); nonoperating days due to repairs, maintenance, and weather; major craft failures; and comments on operations over specific terrain conditions along with the weather conditions encountered. Minor failures are indicated in Appendix C.

CLIMATOLOGICAL CONDITIONS

During the period of craft operation at Point Barrow, the temperature, wind (velocity and direction), visibility, and precipitation were generally typical of the weather reported in previous years (Appendix D). Figure 13 shows the daily maximum and minimum temperatures in the vicinity of Barrow during the test period.

DAILY OPERATIONS

Figure 14 indicates day-to-day craft operations including the last phases of testing in the continental United States (CONUS) and transportation of the test craft in March. Table 2 gives the history of the weekly operating hours and the corresponding man-hours of maintenance. A daily schedule of events is contained in Appendix E.

OPERATIONAL PROBLEMS

Basically, the test craft was designed and constructed to operate over water. Therefore, its performance over the many different terrains and obstacles encountered during the trial period was a significant indication of adaptability to the Arctic environment. The techniques adopted to operate the craft varied with the type of surface encountered and with the experience and the skill of the craft operator. In fact, it is these two characteristics of the test craft operator that enabled the successful completion of this test program.

Operation over Snow-Covered Smooth Ice

During most of the year (mid-September through late June), Elson Lagoon where most of the winter testing was conducted is frozen to depths from 6 to 8 ft and covered with hard-packed drifted snow. Before

thawing starts in late May, this surface is extremely flat (tabletop land) and relatively smooth, and provides an ideal test area (50 square miles) for an SEV. The test craft operated comfortably over this area at speeds up to 60 knots.

Since most of the snow was hard-packed drifted snow, air-blown snow from the cushion at no time hampered craft operation. During the limited time the craft operated in snow storms and over fresh blown snow, the windshield wipers and the supply of heated air to the windshield were inadequate to prevent ice buildup on the windshield.

During the second week in June, the temperature rose to +35 F, and the light, dry powder snow became heavy and wet. This, coupled with the operating technique used (low cushion pressure) caused the rear bags to be filled with snow.

The craft left a visible track on all the snow surfaces it crossed, and it was never able to move without evidence that the rear bags were dragging.

Operation over Water

Since the craft operated over open water for only very short periods and when the temperature was well above freezing, there was no accumulation of ice on the structure. The only difficulty during over water operations was related to the damage sustained by the craft in the 1971 Marginal Ice Zone studies (see page 24).

Operation over Pressure Ridges

Pressure ridges adjacent to the water-land interface around the Point Barrow area were the most severe obstacles encountered by the test craft.[6] Figure 15 gives an idea of the range of heights found in a typical pressure ridge. Enroute to and from the test area at Elson Lagoon the craft usually maneuvered through the fringe areas where an occasional piece of ice protruded (3 to 5 ft heights). When required, the test craft operator was usually successful in finding low sections that could be crossed.

Operation over Tundra

Two types of tests were undertaken on the tundra around Point Barrow: an operational-type mission from NARL over Elson Lagoon to Tekegakrok Point and then inland to Ikroavik Lake. This route (Figure 16) was selected because it was rather remote from the NARL complex and would not interfere with experimental work by other scientific groups at NARL. The tundra in this area is relatively flat, similar to tabletop land in the midwestern part of CONUS, and the size or depth of any depression is not obvious until one is directly upon it. Normally, all trails depicted on maps of the Barrow area are depressions (gullies). During this mission, the test craft became stuck while attempting to cross an existing tractor trail (Figure 16, Point C). Because of the flat nature of the tundra, the operator was unaware of the depth and width

of this depression until the craft was upon it. As the operator attempted to turn away from this depression, the left side of the craft slid into the tractor trail (3 to 4 ft deep). All attempts by the crew to push or pull the craft from the tractor trail with the craft "on cushion" failed, and a weasel from the NARL complex was needed to finally dislodge it. In addition, the operational nature of this mission provided the craft operators with first-hand experience of how such a test craft "handles" on tundra.

The second type of test conducted on the tundra was on behalf of CRREL environmental study (see page 24). During all operations on tundra, the SEV left a visible track in the grass and escaping air from the cushion blew dead vegetation onto the craft. The windshield wiper kept the windshield clean, but it was necessary to clean the air intake filters and the craft after each day of operation.

Operation over Pack Ice

In an operational mission over pack ice, the craft encountered and successfully negotiated pressure ridges up to 5 ft in height. Again, the skill and experience of the operator determined the procedures, the technique, and the success of crossing these pressure ridges.

Like tundra, pack ice "looks flat" until the test craft is directly upon it (150 ft). Therefore, the craft operator must be able to judge the best course from afar and then negotiate the "selected course." The craft operator generally preferred to follow open water whenever possible and operated the craft over pack ice only when absolutely necessary. Despite careful attention to the above conditions, the test craft did get lodged on one pressure ridge. After unloading the crew, the operator was able to maneuver the craft off this ridge by utilizing the puff ports and varying the cushion height. A similar incident also occurred in transversing a deep melt pond. Although the operator exercised extreme care in crossing the pack ice, the under side of the test craft struck "quite hard" on several occasions, and damage was sustained by the under side and the lateral stability bags.

SUMMARY OF MAINTENANCE

The maintenance information contained in this report was obtained from the records of the U. S. Coast Guard Air Cushion Evaluation Unit.[9] These records include the craft maintenance log, weekly report by the officer in charge, and daily flight records (Department of Transportation CG4377 (Rev. 11-69)). Table 3 lists by major subsystems the man-hours required for scheduled, unscheduled, and "other" maintenance. Here scheduled maintenance is defined as that performed at designated periods.[2,10] Unscheduled

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[9] U. S. Department of Transportation–Coast Guard, "Air Cushion Vehicle Evaluation–San Francisco, California and Point Barrow, Alaska–(1 January 1971–31 August 1971)," Report ACV EU 3960-01 (Oct 1971).

[10] U. S. Department of Transportation, "Operating and Maintenance Manual, the United States Coast Guard (1970)".

maintenance includes all minor repairs to the test craft and related equipment that required attention during normal operations.

SPECIAL ENGINEERING TESTS AND RESULTS

PHYSICAL PROPERTIES OF THE TEST CRAFT

The weights and moments of inertias listed in Table 4 are for the test craft equipped with the data acquisition system and flexible skirts system.[11] The data do not include any equipment installed prior to the craft departure from Ames (height sensor, static probe, Newell recorder rack) or those added at the Coast Guard Station at Fort Point, California. Other test apparatus was designed and fabricated by NASA personnel. Figure 17 shows NASA personnel utilizing some of the test apparatus.

On the basis of this experience, it was concluded that the experimental determination of craft physical properties is an involved and expensive process. Accordingly, it is recommended that reliance be placed solely on appropriate analytical methods for determining such physical characteristics as moments of inertia for large future SEV crafts.

DYNAMIC RESPONSE OF THE TEST CRAFT

Known inputs were applied at given locations and directions to define the structural response and behavior of the test craft. It was felt that such a series of tests would shed light on the general dynamic response of SEV lightweight aluminum structures and have application to the substructures of the larger craft envisioned as the ultimate outcome of the ASEV program.

All tests were conducted at the U. S. Coast Guard Facility at Fort Point (San Francisco), California with the propulsion system shut down and the craft suspended by its four lifting pads from a mobile gantry crane (Figure 18). Details of the procedures and testing sequences have already been reported.[12]

The test craft structure was found to exhibit four predominant frequencies between 13.5 and 24.4 Hz. These involved a major portion of the hull and nacelle structure. Tables 5 and 6 summarizes all of the discernible resonant frequencies. The buoyancy tanks showed a sharp local resonance at 33 Hz. The measured critical damping ratio of about 4.5 percent is considered high in comparison with those of typical aircraft structures. The maximum response observed at the nacelle ($\pm 9.4 \times 10^{-3}$ g/lb of force) occurred at 13.5 Hz in the athwartship direction, and the maximum response observed at the bow ($\pm 0.65 \times 10^{-3}$ g/lb of force) was at 13.7 Hz in the vertical direction.

It was concluded that the critical damping ratio on larger SEV's can be expected to exceed typical ratios for aircraft structures (i.e., above 1–2 percent).[12] This is attributed to structural differences between aircraft and SEV's. The more stringent requirements on aircraft (weight restrictions and large dynamic forces) result in a more efficient structure which has fewer energy dissipation points. On the other hand, with its many separate substructures and its extensive skirt system, the SEV structure has many areas of potential energy losses.

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[11] Jackson, C., "Same Notes on the Physical Properties of a Ten-Ton Surface Effect Vehicle," Unpublished notes from the National Aeronautic and Space Administration, Ames Flight Test Center (Aug 1971).

[12] Hagen, A., "Mechanical Shake Test on an SK-5 Air Cushion Vehicle," NSRDC Evaluation Report SAD-3TE-1962 (Feb 1972).

The fundamental resonant frequencies of larger SEV's would be expected to be lower than those measured on the test craft. This can be illustrated by geometrically scaling up the test craft from 10 to 100 tons. If the geometry and the mass distribution are both scaled up by the same factor and the same materials and methods of construction are used, the hull fundamental frequency would drop from 13.7 to 6.2 Hz. However, proper design of a large vehicle may require a different configuration, and an increased stiffness/mass ratio would raise the fundamental frequencies. There is a possibility that resonant frequencies (10 Hz or lower) may involve the entire structure of a large SEV.

VIBRATORY RESPONSE OF THE TEST CRAFT

The machinery normally used in SEV's includes gas turbines, axial or centrifugal fans, air propellers, and a number of gears and transmission shafts. These machinery items provide multiple sources of vibratory excitation at several frequencies. When coupled with a fairly light flexible structure, they can easily result in a noisy craft. Care must be exercised during the design phases to avoid coincidence of the natural frequencies of the structure with machinery-induced excitation frequencies.

As background to this portion of the program, recall that although most aircraft propellers are tractors, SEV's favor pusher propellers. Since the supporting structure is ahead of the propeller on the test craft, the resulting flow of air is distributed to the propeller in a nonuniform pattern. This causes the load on each blade of the propeller to vary with a period that corresponds to one revolution and results in cyclic stresses on the propeller blades. In order to calculate the forces on the propeller shaft and bearings and account for all phase differences the individual loads on each blade must be added. In addition to these cyclic forces, any propeller blade creates a low pressure area ahead of the blade and a high pressure area behind it; both travel with the blade and cause blade frequency pressure fluctuations on any nearby surface. Another cause of uneven load occurs when SEV propellers are subjected to angled inflow, at times 90 deg from the direction the propeller is facing.

Accordingly, the static thrust developed by the test craft was measured at different propeller speeds and pitch settings. To distinguish between machinery–excited and operational–induced vibration (e.g., as a craft crosses terrains), the frequency and magnitude of machinery–excited vibration were determined with the test craft tethered. This also allowed greater control over rpm, pitch, and power. The tethering ring included a force gage for measuring thrust. In addition, craft vibration was measured for several operating conditions to relate measurements of machinery vibrations for the tethered craft to actual craft operations.

Details of the procedures and testing sequences have already been reported.[13]

The results of the acceleration measurements in the tethered condition showed that machinery excited the craft primarily at blade and twice blade frequency. Vibration levels were fairly low at the bow but

[13] Antonides, G., "Machinery Vibration Measurements on SK-5," NSRDC Evaluation Report SAD-5TE-1962 (Feb 1972).

reached 1 g at the stern; the exciting frequency was relatively high compared to the natural frequency of the main hull structure. These 1-g levels would be uncomfortable for humans and could damage many types of equipment. This vibration may account for the many difficulties experienced with the stern-mounted velocity sensor; see Appendix F.

On the nacelle, the vibration levels read 6 g, indicating that large propeller forces were being transmitted through the bearings. The resulting stresses in the nacelle were fairly low (less than 1000 psi) so structural failures would probably occur if supporting struts, bearings, or the like were not properly designed for such high loads.

Figure 19 indicates the mean forces at the propeller bearing. Note that the high athwartships forces appear to be toward the portside, indicating a higher load in the upper rather than in the lower half of the propeller disk; this is contrary to what was expected of a right-handed propeller. The vertical lateral force was directed upward, indicating a greater load in the starboard side of the propeller disk. The highest alternating forces occurred at blade frequency in the longitudinal direction. Here the high levels (± 740 lb at full power) were caused by the coincidence of blade frequency with a longitudinal resonance (Figures 20–22).

Figure 23 shows the mean thrust throughout the range of power turbine rpm. The load cell measurements were lower throughout the entire speed range because of thrust deduction, and they were lower in the range below 85 percent rpm because the craft was not fully on cushion. At higher turbine speeds, the skirt fingers barely touched the ground and so the load cell measurements should be fairly accurate. The pitch and compressor rpm are also given in Figure 23. At about 75 percent power turbine rpm, the compressor turbine rpm was at 100 percent, indicating that maximum power was being used. In order to increase power turbine rpm beyond that point, it was necessary to decrease propeller pitch as shown in Figure 23.

It was concluded on the bases of these tests that a detailed examination is warranted of the differences between the accelerations and forces measured while the craft was tethered and underway. Furthermore, the presence of highly nonuniform wakes and large lateral propeller bearing forces must be taken into consideration when designing shafts and seals for future SEV's.

CRAFT CAPABILITY TO CROSS OBSTACLES

As the craft crossed various obstacles, its dynamic response was measured along with the bending and torsional loads introduced into its structure and the forcing functions created when the cushion encountered obstacles. Combined with this series were tests to determine the dynamic behavior of the cushion over a flat surface. These latter data were taken in order to determine steady-state cushion efficiency, the magnitude of changes in cushion volume rate of flow due to oscillations in cushion pressure, the magnitude and phase relationship of cushion and plenum pressure oscillations, the correlation of vehicle motions with cushion pressure changes, etc.

The discrete obstacle tests were performed by "flying" the craft over obstacles of different shapes and sizes up to 4.5 ft in height at speeds up to 60 knots. Figure 24 illustrates typical obstacles for this series of tests and Figure 25 shows the craft crossing a wooden triangle obstacle at Alameda.

One of the most interesting lessons in regard to obstacle design and fabrication was learned during the familiarization phase at Alameda. Attempts to clear obstacles designed on the bases of a current theory of pressure loading resulted in destruction of the obstacles because of skirt finger drag (see Figure 26).

As the craft crossed obstacles, the fingers attached to the peripheral skirts dragged across the obstacle and caused considerable damage as evidenced by the debris remaining in the area after each crossing. In addition, the fingers developed an overturning moment which caused the obstacle to rotate and in some cases strike the hard bottom structure of the craft (see Figures 27 and 28). Figure 29 shows the craft crossing a natural obstacle (gravel bank) at Barrow; again, the fingers dragged across the obstacle and eroded the bank.

Preliminary data have already been reported[14] on the dynamic pressure of the vehicle and cushion as the craft crossed discrete obstacles. Figure 30 illustrates peak and characteristic impact, drop, and rebound accelerations. It is interesting to note that the impact acceleration was consistently the smallest in magnitude.

Published preliminary results[15] compare structural bending and torsional load to the dynamic response of the craft as it traversed various obstacles; the test plans and procedures utilized to collect these structural data are also given there.

Lift fan speed and plenum pressure measurements were utilized to develop an empirical method for estimating the total pressure, flow rate, and efficiency of the craft lift fan. The results of this empirical method are shown in Table 7.

A tabulation of engineering test data including, vehicle accelerations, cushion system pressures, and lift fan speed (rpm) pertinent for the analysis of cushion dynamics has already been reported.[16] The total pressure and flow rate at various fan efficiencies are shown in Figure 31. In addition, the present data show that as the craft encounters an obstacle, air is forced from the skirt and enters the plenum. The forward cushion pressure drops rapidly to or below atmospheric pressure, and the increasing plenum pressure causes the vehicle to heave and pitch upward. When the forward portion of the skirt clears the obstacle, it quickly returns to its original shape. When the test craft has passed the halfway mark on the obstacle, a similar expansion of air takes place in the rear cushion.

Additional results obtained from the cushion data[17] indicate that the skirt or fan pressure transients are only 40 percent of the plenum pressure transients and that the skirt pressure is a composite of the plenum pressures and heave frequency (approximately 1 Hz) of the cushion.

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[14] Howe, H., and J. Durkin, "Preliminary Results of Tests of a Ten-Ton Surface Effect Vehicle in the Arctic–Discrete Obstacle Crossings," NSRDC Technical Note AL-244 (Jan 1972).

[15] Zwenig, E. A., et al., "SK-5 Structural Trials and Tests for the Arctic Environment," NSRDC Tech Note SD 173N225 (Oct 1972).

[16] Shank, Jr., S. R., and J. S. Houston, "SK-5 Obstacle Crossing Data Related to Cushion System Dynamics," NSRDC Tech Note 27-229 (Apr 1972).

[17] Howe, H. J., "Analysis of Discrete Obstacle Crossing Data from Tests of a 10-Ton Surface Effect Vehicle in the Arctic," NSRDC Report (AL-TN 259), (in preparation).

The following conclusions are drawn from the discrete obstacle crossing tests:

1. After an obstacle has been passed, accelerations at the bow and the center of gravity are very similar, indicating a heave rather than a pitch motion. this is due to pitch damping.[16]

2. After an obstacle has been passed, cushion pressures go back in phase, another indication of heave motion.[16]

3. The natural frequency of the vehicle in heave is approximately 1.0 Hz regardless of whether the acceleration waveform or the pressure waveforms is used.[16]

4. Static experiments and calibrations undertaken to investigate longitudinal and torsional bending involve bulky weights and coupled support systems. Accordingly, consideration should be given to the use of scaled tests and computer analysis techniques for such structural analyses.[15]

5. Criteria should be developed for a controlled test course to measure dynamic response to a random terrain.[15]

6. At best, the operator's estimate of craft speed is generally "poor."[14]

7. It is difficult to hold cushion power constant at a given speed because the turbine speed can be readily changed by variations in propeller pitch and craft velocity. Hence, if flight at a given cushion power is required either for testing or ordinary craft operation, an automatic turbine speed control system is required.[13]

CRAFT TURNING CAPABILITY

The craft rudder, skirt lift, and puff port controls were utilized to obtain turning radius, turning velocities, and time to turn as a function of constant approach velocities. The influence of the terrain and related skirt drag on craft turning capabilities was also investigated. The data will be utilized in conjunction with parametric analysis studies related to the turning and control capabilities required for large SEV's.

Church has described test procedure and data acquisition requirements[18] and the results of the data analysis.[19] It had been planned to use the doppler radar to measure directional and lateral velocities of the test craft, but it was inoperative at that time and the instrumentation system developed to track the craft position in turns was used instead.

This tracking system consisted of two surveyor transits, potentiometers, necessary signal conditioning electronics, and a two-channel printer to record the potentiometer output. The transits were located at a

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[18] Church, R. W. et al., "Preliminary Results of Tests of a Ten-Ton Surface Effect Vehicle in the Arctic–Turning Characteristics," NSRDC Tech Note AL-242 (Jan 1972).

[19] Church, R. W., "Analysis of Turning Test Data Obtained from Tests of a 10-Ton Surface Effect Vehicle in the Arctic," NSRDC Tech Note AL-271 (Aug 1972).

known distance apart and approximately parallel to the course to be flown by the test craft. Each transit was manually operated to follow the craft as it transversed each course at a constant power setting; see Figure 32. The same test procedure was repeated later for tests over the rough polygon surface of a dry lake bed (i.e., tundra); see Figure 33. Figure 34 presents the run conditions and control settings for the turning test over snow together with the craft paths for these runs. Similar information for the turning tests on tundra is given in Figure 35. The skirt lift jacks were operated fore and aft on either the port or starboard side, and the puff ports were operated in various combinations.

The test data can be utilized to determine the control that displaces the test craft from its initial heading with the greatest deviation for a given speed. In addition, the acceleration measurements enable determination of the control that can rotate the craft most quickly.

CRAFT DECELERATION AND STOPPING CAPABILITY

The effectiveness of two different methods of decelerating and stopping a SEV were evaluated. The test procedure, data acquisition requirements, and results of the data analysis have already been reported.[20,21] Briefly, a tracking system established at fixed ground stations adjacent to the test area recorded the position history as the test craft performed a deceleration maneuver from various initial speeds.*

Two methods of craft deceleration were evaluated:

1. Reverse propeller pitch only was used, i.e., negative thrust was created by reversing the propeller pitch to the maximum negative angle.

2. The craft was maneuvered into a pirouette by yawing it 180 deg and then increasing the propeller pitch angle to apply full available thrust.

Although deceleration by cutting off the power to the lift fan and thus dropping the lift cushion is frequently used in operations over water that method was not employed for these tests.

The deceleration tests were conducted on the frozen snow-covered surface of Elson Lagoon (Figure 36) and over tundra (Figure 37). The initial propeller pitch, turbine speed, and compressor speeds were specified; see Tables 8 and 9. The deceleration maneuver started as the craft passed between two marker flags. The position histories of the test craft were determined from the tracking data; see Figures 38 and 39. Time to stop is not given for the pirouette method because it was difficult to repeat the control settings with any consistency. Figure 40 illustrates a representative time history of the propeller pitch angle during a Method 1 (reverse propeller pitch) deceleration test, and Figure 41 illustrates the representative time histories of the propeller pitch and rudder deflection during a Method 2 (pirouette) deceleration test.

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[20] Scheurich, P. R. et al., "Preliminary Results of Tests of a Ten-Ton Surface Effect Vehicle in the Arctic–Deceleration," NSRDC Tech Note AL-241 (Jan 1972).

[21] Scheurich, P. R., "Analysis of Deceleration Data from Tests of a Ten-Ton Surface Effect Vehicle in the Arctic," NSRDC Tech Note AL-257 (in preparation).

*The velocity measuring device on the craft was inoperable at this time, and data from the tracking instrumentation system were used to determine the ground speed of the craft as it entered the required maneuver.

The analysis of these data indicated some differences in the two methods under the test conditions investigated. In general, both required shorter distance to stop the craft over snow than over tundra. However, both deceleration methods required large distances to stop a 10-ton SEV (e.g., approximately 650 ft for an initial craft speed of 35 knots). It is therefore imperative to investigate other means for decelerating and stopping large SEV's (e.g., auxiliary power, ground contact devices, etc.).

Tests to evaluate craft acceleration capability were limited to only one power setting (compressor = 97 percent, turbine = 97 percent). The line drawn through the data points in Figure 42 gives an approximation of the acceleration capability of a 10-ton SEV at 97 percent of available power.

A comparison of the experimental results with present analytical methods for predicting craft deceleration and stopping characteristics indicates the need for an improved analytical method. It is planned to devise a modified method to predict the deceleration and stopping characteristics of the projected large-scale Arctic SEV designs now under study.

DEFORMATION CHARACTERISTICS OF THE FLEXIBLE SKIRT

This series of tests was conducted to study the static and dynamic deformation characteristics of the flexible skirt, to provide a direct measurement of vehicle skirt drag, to determine the magnitudes of the drag components (i.e., aerodynamic, momentum, trim, and skirt), and to describe related characteristic engine and fan performance.

The test procedure, data acquisition requirements, and analysis of the data have already been reported.[22,23]

Briefly, the test craft had a constant power setting while traversing two parallel courses, one relatively smooth and the other typical of a rough snow and ice surface (Figure 43). Since changes in craft velocity were expected to be relatively small, the changes in the aerodynamic and momentum drag created can be considered negligible. Accordingly, it was felt that the difference in the resultant ground speed for each course (at a constant power setting and similar wind conditions) could be attributed primarily to skirt drag. Had the velocity changes been large, the other drag components would have had to be considered.

In theory the skirt drag over the smooth terrain (if truly level) would also be negligible, so that the skirt drag created by the rougher terrain would be approximately 100-percent of the actual skirt drag. However, skirt drag of some finite magnitude most assuredly was created over the smoother terrain; thus, the magnitude of the skirt drag must be regarded as a difference in skirt drag created by the surfaces.[22]

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[22] Scheurich, P. R. et al., "Preliminary Results of Tests of a Ten-Ton Surface Effect Vehicle in the Arctic Skirt Drag," NSRDC Tech Note AL-243 (Jan 1972).

[23] Kidd, A., "Analysis of Skirt Drag Data from Tests of a Ten-Ton Surface Effect Vehicle in the Arctic," NSRDC Tech Note AL-256 (in preparation).

The test procedure was repeated at different power settings (Table 10) to determine the variation of skirt drag as a function of forward speed. Similar tests were conducted later in the summer over two types of tundra surfaces.

It had been intended to utilize the doppler radar for measuring the directional and lateral velocity of the test craft, but that item was unavailable (see Appendix F), and another means of determining true ground speed was necessary. Accordingly, the tracking system that had originally been intended for gathering data for craft turning characteristics was also used to measure its average velocity. Considering the environment and the minor operating problems, this tracking system performed reasonably well during the skirt drag tests over snow. However, additional backup data were gathered by measuring with stop-watches the time required for the craft to travel 0.01 nm at a constant power setting along each course. Transit (data) readings that recorded the angular position of the test craft were used as input to a computer program which calculated the X-and Y-position coordinates with respect to the transits. The results (Table 10) indicate that for the same compressor, turbine, and propeller pitch setting, the test craft transversed unprepared snow (Course B) at a lower velocity than over prepared snow (Course A).

The same test procedure was repeated later for two types of tundra surface: the rough polygon surface of a dry lake bed and the natural tundra that bordered it (Figure 44 and Table 11). The test runs were staggered in 1000-ft intervals with data points plotted 2 sec apart. No additional backup time measurements over a known distance were recorded in this series.

Figure 45 shows the craft tracks for the various runs and Table 11 includes the average craft velocities for the indicated test conditions. For the same compressor, turbine, and propeller pitch settings, the test craft took longer to traverse the polygon hard surface than the natural tundra surface. This may have been caused by air leakage through the cracks in the dry polygon surface.

During both sets of skirt drag tests, the on-board data acquisition system continuously recorded the operating characteristics of the test craft on magnetic tape. Propeller pitch angle, turbine speed, and compressor speed were analyzed to determine whether constant power and thrust level had been maintained throughout a test run. It was determined that the initial values of these characteristics as shown in Tables 10 and 11 had been maintained relatively constant during each run.

Two methods for predicting thrust[22] were used to calculate the total drag, aerodynamic drag, and skirt drag for test runs over various surfaces. Values are given in Table 12 in relation to that obtained over smooth ice for the conditions of a specific run. The available data will be analyzed further to determine the actual skirt drag (in pounds) created by different operating surfaces at different speeds. Because the test conditions and number of runs were limited, it is recommended that more detailed tests be accomplished in order to upgrade methods for predicting skirt drag. No presently available method is based on solid experimental evidence.

The high speed photographic data will be studied more carefully to provide an effective means of displaying the present results.

CRAFT DIRECTIONAL STABILITY

This series of tests was carried out to determine whether an SEV can experience a situation analogous to some pilot/aircraft control loops. In such a situation, the pilot applies a corrective control action that causes the aircraft to oscillate and/or diverge about the intended position. Accordingly, directional stability derivatives of the test craft were measured and the effectiveness of various directional control devices (rudders, puff ports, and skirt lift) were measured as the test craft operated in a pilot-induced oscillatory mode.

The procedure[24] called for the test craft operator to hold an initial heading within 15 to 25 deg by activating each of the directional controls (rudders, opposite corner puff ports, and opposite corner skirt lift) of the craft separately and in all combinations.

This experimental arrangement was considered analogous to the situation where the operator attempts to hold a constant heading while the craft experiences period disturbances from a crosswind that is alternately blocked and unblocked by a nearby line of ridges and peaks or by shed eddies (Figures 46 and 47).

The craft was extensively instrumented for these investigations. For example, an electric-driven gyroscope was installed to meet one special requirement, namely, the time history of the change of heading of the vehicle with respect to its track. This instrumentation also enabled a quantitative measure of the effectiveness of directional control via the rudders, puff ports, and skirt lift.

The ways in which the vehicle track varied during the runs illustrated in Figure 48 are typical for all the runs of this investigation. These tracks show the response due to a slight crosswind as well as to control actuation. On the basis of the track plots (Figure 48) and the predetermined sampling frequency from the tracking system (sighting points on the craft per second) it was found that the operator was able to keep craft speeds to within ± 5 knots of those requested.

Typical variations of heading (in degrees) with time is shown in Figures 49–52. There was little indication of oscillation divergence in the data. The pilot was able to maintain a fairly constant heading oscillation at 20 knots (Figure 49) but there was an indication of approaching divergence for rudder actuation at 50 knots. The higher yaw moment output that accompanied the higher vehicle velocity was sufficient to cause the operator to take corrective action that caused a divergence about the original heading. Up to the time limit of the data tracking (60 sec), the heading went out to 45 deg and showed signs of continuing to increase. It does not appear that a pilot-induced oscillation would create a problem for the craft used in this program. However, at high craft speeds, the operator can lose directional control of a craft that has marginal directional stability.

A comparison of the effectiveness of the various control devices indicates that skirt lift (opposite corner actuation) was ineffectual as a directional control device on this craft and that the amplitude of the heading oscillation for combined actuation of puff ports and rudders was approximately the same as for rudders only.

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[24] Ozarko, H.S., "Preliminary Results of Tests of a Ten-Ton Surface Effect Vehicle in the Arctic–Pilot-Induced Oscillation," NSRDC Tech Note AL-246 (Jan 1972).

CRAFT TERRAIN SURVEILLANCE CAPABILITY

Three candidate sensors for Arctic SEV obstacle detection were utilized: 10-and 94-gHz radar and 1.06-micron laser. Actual radar returns from typical Arctic terrain (pressure ridges) were recorded under a variety of different conditions. These radar returns were to be used to develop and evaluate optimum data-processing and display techniques for extracting height (or altitude) of pressure ridges and range information. Results of the terrain sensing tests were used to evaluate the characteristics of the radar returns from the candidates sensors; and ground truth data were collected for correlation with the sensor data. Other objectives included determination of propagation losses over the test terrain and the later use of sensor data in hybrid simulation.

For the data collected during May, the 10-gHz radar and the 1.06-micron laser were mounted on the test craft. The June data were taken with all three sensors located at a fixed site on shore; Figure 53 shows two of the sensors. The June test site is shown in Figure 54.

In both months, analog video data were recorded while the sensors scanned a test field that contained typical ice obstacles. Bad weather (cloudy overcast skies) precluded use of aerial photography during the May test period, but complete photographic mapping for ground truth data (Figure 55) was accomplished in June.

Terrain scans for the laser and 94-gHz radar were accomplished manually. A precision rotary table provided the azimuth scan and a tilt mechanism on the table provided the elevation scan. To obtain the 10-gHz data, a scan controller was added to the test craft radar to allow slow scan operation and reversal. All data were recorded on a high-speed 15-MHz recorder and two backup recorders. The basic test configuration is shown in Figure 56 and a sample GHz PPI sector created from the data collected on the processing system is given in Figure 57. A more detailed discussion of the procedures used is available in a series of APL reports.[25-28]

Analysis of the collected data is continuing in an attempt to obtain detailed correlation with the contour maps generated from the aerial photography and the recorded radar returns.

Although the analysis is not yet complete, several definitive conclusions have already been reached together with specific recommendations.

1. It is possible to develop a 1.06-micron sensor to meet the obstacle detection objectives in clear weather, but such a device will not operate effectively in even light fog. It is anticipated that a 10.6-micron

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[25] Thompson, T., "Terrain Sensing Tests–June 1971," The Johns Hopkins University, Applied Physics Laboratory Report S3R-71-271 (Aug 1971).

[26] Schneider, J. D., "Layout and Performance of the 94-gHz Radar," The Johns Hopkins University, Applied Physics Laboratory Report S3R-71-225 (Jul 1971).

[27] Schneider, J. D. and T. A. Kehoe, "Performance Specifications Update on 94-gHz Radar," The Johns Hopkins University, Applied Physics Laboratory Report S3R-71-318 (Sep 1971).

[28] Smith, L., editor, "Radar Field Test Point Barrow, Alaska," The Johns Hopkins University, Applied Physics Laboratory Report APL-SEV-003 (Sep 1972).

laser frequency will have a significant weather advantage over the 1.06-micron laser. A test program in the Arctic environment is needed to establish the character of radar returns from ice and snow at the 10.6-micron wavelength.

2. The azimuth beamwidth of the 10-gHz radar system tests was too wide for shadow processing, and dynamic range limitations in the analog recording system are not compatible with effective shadow processing.

3. A 94-gHz radar has great promise in that the returns from obstacles in the test area were well above the background noise. The performance of this sensor was not noticeably degraded in the fog conditions experienced during the tests (visibility down to 1000 ft). Accordingly it is recommended that a more complete 94-gHz experimental system and an improved data recording capability be developed and tested in the Arctic.

4. It is also recommended that more detailed propagation data be developed at 94 gHz, and at 1.06 and 10.6 microns.

HUMAN FACTORS ENGINEERING ASPECTS

Because the primary objective of the test program was to use the SEV as a baseline to establish design criteria for a large Arctic SEV, it was not the intent to use it to evaluate either the adequacy or the lack of human factors engineering in the test craft. However several problem areas related to that field were easily identified and will be discussed briefly here. This is not to suggest that these were the only areas in which problems related to human factors were identified; see Hall et al.[29] The discussion in this report is limited to subjective reactions of the craft operators and a brief mention of the difficulty experienced by maintenance personnel.

To obtain a subjective appraisal, a human factors specialist at Point Barrow administered a questionnaire constructed for operator identification of problems or potential problem areas related to craft control, navigation, communication, habitability, etc. Some of the preliminary problems identified as a result of this questionnaire are:

1. Environmental Conditions – The use of an SEV will be limited during white-out conditions (a) because the operator is disoriented and (b) because the high winds and blowing snow disturb radar reception.

2. Displays and Controls – The operators suggested several different arrangements for the controls. Displays for the power turbine and power assists for the rudders were of particular interest.

3. Communication – Radio communication fadeout in the Arctic is considered serious enough to affect the mission.

4. Safety Devices and Survival Resources – The operators made several suggestions regarding the types and amount of safety devices and survival resources that would be desirable on a SEV operating in the Arctic, e.g., a self-jacking system aboard the craft and a winch capable of freeing a stuck craft.

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[29] Hall, C. C. et al., "Human Factors Problems Associated with Operation and Maintenance of Surface Effect Vehicle in the Arctic Environment," NSRDC Report 6-231 (Nov 1971).

5. Glare – Problems from internal and external visual glare were sufficiently serious to warrant attention in future vehicle design. The glare experienced inside the craft was attributed to overly bright displays on the control panels and the reflection of interior lighting systems on the windshield. Sun shining on snow-covered surfaces was refracted through the windshield covered with a salt residue from sea water. This external glare was probably more objectionable and severe than internal sources. Tinted windshields and/or sunglasses may alleviate the situation.

The human factors questionnaire was also utilized to identify problems that affected the maintenance personnel. Thus responses indicated a need for the development of tools that can be used with bulky mittens, disposable shelters to accomplish maintenance, and clothing and other accessories to cope with the unfavorable environment.

Preliminary analysis has indicated that although problems related to human factors do exist, they will not prevent the effective operation and maintenance of SEV's in an Arctic environment. Further analysis and correlation of these problems will be extremely valuable in establishing the human factors design criteria for the large Arctic SEV.

CRAFT EFFECTIVENESS AS A MOBILE DATA-GATHERING PLATFORM

In support of an ARPA-funded effort at the Arctic Submarine Laboratory (NURDL) San Diego, California, the University of Washington is conducting studies of the oceanographic and acoustic characteristics associated with the Arctic marginal ice zone (MIZ). The purpose of the test reported here was to demonstrate the ability of an SEV to serve as a mobile data-gathering platform in support of the MIZ studies. For this demonstration, the data acquisition system was removed from the SEV, and a portable salinity-temperature-depth data acquisition system was installed in its place (Figure 58).

The test plan called for the SEV to be stationed for a 2-week period at one of two camps (Alpha and Bravo) established 7 miles apart on a ice floe, approximately 75 miles west of Barrow in the Chukchi Sea.

The craft was loaded with supporting gear for the tests and carried tents and survival gear for its own five-man crew. It departed from the NARL Barrow on the afternoon of 1 August 1971 and reached Camp Bravo 4 hr later. The temperature was +28 F.

The transit to Camp Bravo was over rough ice fields and open leads. After clearing rough ice packed along the shore at Barrow, the craft operated along an open lead for an hour then through broken ice fields for another hour before reaching the ice floe. The remainder of the operation was over pack ice extending from 2 to 4 ft in height. No difficulties were experienced other than in navigation. The craft radios did not function properly and helicopters from the Coast Guard ice breaker NORTHWIND assisted the test craft in navigating the last few miles to Camp Bravo. The SEV and its crew then went on to Camp Alpha 7 miles to the northwest across rough ice and arrived within 45 min.

The following day, the crew set up tents at Camp Bravo and prepared for test operations with the University of Washington scientists. The test plan (Figure 59) called for dunking the data probe through the ice at 1-mile intervals along preselected courses. Dip points were selected along open leads, and each dip required about 5 min to accomplish. This type of operation permitted the flexibility desired by the scientists and would not have been possible with a helicopter.

In addition to participating in the scientific experiments, the SEV proved very valuable in providing logistic support; it moved personnel to specified locations on the ice and shuttled personnel and supplies between the two camps, the NORTHWIND, and Barrow. Table 13 indicates the overall participation of the SEV in the MIZ studies.

After the first week of operation, a change in the position of the two camps necessitated a change in the test plans. In the past, once established, the ice camps and the ice flow usually remained in a general area. During this exercise, however, the wind blew continuously from the northwest for 2 days at an average velocity between 12–15 knots. The ice floe on which the camps were located was pushed in an easterly direction until it was caught by the Northern Alaska Littoral Current. This current carried the ice camps from the Chukchi Sea around Point Barrow (Figure 60) into the Beaufort Sea.

As a result of this movement, the two ice camps became separated and some of the planned experiments had to be abandoned. A further complication arose because after it rounded Point Barrow, the ice floe containing the test craft was carried southeast into the "shallow coastal waters" of the Beaufort Sea, an area of little or no interest to the scientists. However, the planned experiments that did not depend on the location of the ice flow (shallow or deep water) were accomplished (i.e., explosive charge drops, limited STD drops, and acoustic studies).

Some interesting operational techniques were developed and some operational deficiencies became apparent during this exercise.[30] First, the operational deficiencies. The test craft began this exercise with its radar and the automatic directional finder (ADF) inoperative. In fact, when it left Point Barrow for the ice floe 75 miles west, all it had was a magnetic compass. However, repair of a broken lead in the ADF antenna on the second day out enabled the SEV to confidently transit between Camp Bravo and NORTHWIND by tracking the beacon at each location. In addition it could determine the approximate position of the ice flow by locating two shore-based radio beams normally used to assist aircraft navigation. Two days after the ADF was repaired (7 August 1972), the SEV transited from the ice floe north of Point Barrow (see Figure 60) to NARL for fuel by tracking the radio beacon at Barrow.

The techniques developed to operate the SEV in and over the ice pack are most interesting. In fact, the skill and experience of the operator determined the success and ease with which the test craft was operated. The ice pack contained both first-year and multiyear ice in addition to large pressure ridges (3–8 ft)

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[30] Shabelski, J. J. and J. U. Kordenbrock, "Operational Observations of a Surface Effect Vehicle during 1971 Marginal Ice Zone Studies," NSRDC Evaluation Report 11-0-12 (in preparation).

and varied from a very open pack to a close pack. Except for cases where it contained a large section of pressure ridges the ice pack in August consisted of ice hills 2–6 ft high dotted with melt ponds. In some places, these ponds had melted through to the ocean.

During this exercise, the SEV operators preferred to operate on the open water as much as possible. In other words, the operators considered that the best route was the one that contained the most water. Route selection was complicated by the fact that the ice packs look relatively flat as one approaches. The relative height of the ice hills and depth of the melt ponds are not easily distinguishable (3 versus 5 ft high) until the test craft is directly on top of the ice and committed to the selected course. If the selected course contained ice hills that were too high for the skirt system, the craft underside struck the ice. Actually, the hard underside structure experienced five or six "hard contacts" with the ice and suffered considerable damage; in one instance, the lateral bags were damaged beyond repair.

By the second and final week of this exercise, it was necessary to terminate all parking on water. The operators then developed an interesting technique for parking alongside NORTHWIND without parking on the water. The operator would select a large piece of ice and lower cushion power until the bow of the SEV was in contact with it. He would then push this piece of ice alongside NORTHWIND and parked the craft on ice. This operation may explain some of the damage the craft sustained along the hinge lines (points where the skirt is attached to the side body).

The following major craft items were damaged during SEV operation (total of 32.8 hr) in support of the 1971 MIZ studies:

1. Lateral bags damaged beyond economical repair.
2. Considerable damage to the hinges attaching the skirt to the craft.
3. Structural damage to the left side body in the bow area.
4. Tears in the bottom of the right rear bags.
5. Structural damage to the right rear hard structure underneath the craft.

Considering the circumstances under which the craft was required to operate, some structural damage was only to be expected.

EFFECTS OF CRAFT OPERATIONS ON ARCTIC TERRAIN

To determine the extent and rate of terrain surface erosion (organic and mineral) and possible damage to vegetation from the action of the SEV peripheral air jet, tests were conducted at two sites: Houghton,

Michigan, and Barrow, Alaska.[31] This report will be concerned only with those tests conducted on tundra in the vicinity of Barrow. Four test sites (wet, relatively dry, stream shore, and high centered polygon) were selected (Figure 61) in order to cover many types of tundra and vegetation. The arrangements of the selected test lanes at the four test sites are shown in Figure 62.

The following dependent variables were either measured or observed: the extent and type of disturbance and damage to terrain surface and its effect on live vegetation, damage to geometrical surface irregularities (polygons), effect on simulated bird nests and eggs and on animals inadvertently subjected to vehicle traffic, vehicle performance and maneuverability in high centered polygon areas, surface temperature, techniques required for the operator to extricate an immobilized SEV, and comparative damage to terrain from similar traffic by the SEV and a light tracked M-29 Weasel. The test sites and test procedures were as follows.[31]

Site 1 was a level, drained lake bottom, with a relatively uniform and homogeneous saturated active layer and vegetation (average depth of thaw 7 in., 0–2 in. moisture content 1200 percent). Six 50-ft-wide test lanes were laid out with a 70-ft-wide control section between each pair (Figure 62) and subjected to the following traffic:

Lane No.	No. of Passes	Vehicle Speed, mph	Direction of Travel
1	1	30–40	North
2	5	30–40	South
3	25	30–40	North
4	25	10	North
5	50	30–40	South
		Duration, min	
6a	Hovering	0.25	
6b	↓	0.50	
6c	↓	1	
6d	↓	2	
6e	↓	5	
6f	Hovering	10	

A corresponding number of passes were made with an M-29 Weasel on the control areas adjacent to Lanes 1, 2, 3, and 5 for subsequent comparison to evidence of SEV traffic. Lane 4 was used to compare the effect on the terrain from low speed traffic with that of high-speed traffic (Lane 3) for the same number of passes (25).

[31] Abele, G. et al., "Effects of SK-5 Air Cushion Vehicle Operations on Organic Terrains," U. S. Army Cold Regions Research and Engineering Laboratory Report (May 1972).

Specific observations and measurements were made over a 100-ft length of each lane. Before-and-after photographs were taken of all lanes; and detailed closeups were made of Lane 3 after 1, 2, 5, 10, and 25 passes.

Site 2 was well drained, relatively level and contained a few low centered polygons and hetrogeneous vegetation (10 in., 0–2 in. moisture content 340 percent). It was considered dry compared to Site 1 (340 versus 1200 percent). Five test lanes were established, as shown in Figure 62, and subjected to the following traffic:

Lane No.	No. of Passes	Vehicle Speed, mph	Direction of Traffic
7	50	20–30	North and South
8	5		South
9	1		North
10	25	20–30	South

Lane No.		Duration, min
11a	Hovering	0.25
b		0.50
c		1
d		2
e		5
f	Hovering	10

Lane 12 was established as an obstacle course in a high relief (up to 4 ft) polygon area a few hundred feet south of Site 2. As at Site 1, a corresponding number of passes were made with the Weasel adjacent to Lanes 8, 9 and 10 (5, 1, and 25 passes, respectively) for comparison purposes.

Site 3 included a narrow stream channel and a land-water interface which enabled the vehicle to travel for a considerable distance over water before exiting to shore (Figure 62, Item c). Observations and photographs were made of the effects on shoreline features after 1, 10, and 25 passes on Lane 13. Lanes 14 and 15 received 10 and 1 passes, respectively, for future monitoring.

Site 4 was a well-drained, high-centered polygon area (up to 3.5 ft high) selected for observation of degradation of raised relief after 1 pass (lane 16), 10 passes (Lane 17), and 25 passes (Lane 18). Some snow was present in the troughs between ploygons.

As expected, the results indicated that the number of craft passes had a very significant effect on the resulting condition of a particular organic terrain. Degradation of the vegetative cover was increased because (1) the weight of the data acquisition system installed for the tests slightly decreased the effective air gap, (2) the skirt fingers were rough and worn and (3) there were broken strakes on the rear bags. In comparison, the immediate degradation or damage produced by the same number of passes with the light tracked Weasel appeared to be more severe than that of the SEV.

The speed of the vehicle had a distinctive effect on the extent of terrain surface degradation. The relative distrubance to the vegetation produced by the skirts was more severe at speeds of 30 to 40 knots than at 10 knots. During prolonged hovering in place, virtually no degradation was observed.

The direction of travel relative to the position of the sun influenced the appearance of the signature, especially when viewed from the air, and may also influence the long-range effect on the thermal characteristics of the vehicle trail because of a possible change in albedo.

Very little air flow was observed under the rear bags of the test craft during operation over the very low vegetation at NARL; the vegetation was bent by the rear bags in the direction of travel and remained in that position in the absence of a sufficiently strong air flow under the bags in the opposite direction. The implication is that the appearance of the vehicle signatures would have been rather different had the vehicle been able to maintain a higher air gap below the rear bags. In that case, a single pass, or even a few passes, might have left no signature at all on this type of terrain.

Figure 63 indicates the effect of vehicle speed; the more gentle drag of the skirts at low speed caused considerably less degradation to the tundra surface. Of course color adds a dimension to photography that is lacking in black and white; see Abele.[31]

The relatively insignificant effect of the air flow alone (skirt drag not present) is illustrated in Figure 64a. There was no recognizable signature from 10 min of hovering, but one SEV pass at high speed (a contact time of only a couple of seconds) at any place on the terrain left a visible trail (Figure 64b). This relative long-range effects will become apparent only after future monitoring and annual inspection of the test lanes; whether one pass is more or less severe than 10 minutes of hovering cannot be evaluated now. It is quite apparent, however, that 25 passes, and certainly 50 passes, have a more severe effect than prolonged hovering for these cushion and skirt characteristics.

Figure 65 indicates the visible effects of one and 25 passes by the SEV and the Weasel. It could be observed that the extent of damage to the vegetation from skirt contact was not uniform throughout the traveled path; areas with even slightly raised microrelief (a few inches or less) sustained more severe degradation than flat, smooth areas.

Because of the drier vegetation and lack of water spray, reorientation (bending) of the vegetation after vehicle passage was not as significant at Site 2 as a Site 1; consequently the direction of traffic in relation to the sun did not influence the appearance (shade or color) of the signature.

Again, the relative effect of skirt drag was more evident than that of the cushion pressure and air flow; the vehicle-terrain contact during 10 min of hovering was longer than during 50 passes, yet the effect on the terrain surface during travel (and the resulting skirt contact) was of considerable severity whereas the effect of cushion air action was virtually negligible during hovering.

A comparison between the 25-pass lane at Site 1 and the 25-pass lane at Site 2 indicates a more severe visible degradation of a wet tundra surface than that of drier tundra for the same number of passes at comparable speeds. (This does not necessarily mean that the long-range effect may also be different.)

In an effort to determine what effect (s), if any, the craft would have on bird life, etc., the following key reference features in Site 2 were chosen:

Position	Features
1	Level area, sphagnum moss clump surrounded by sedge
2	Simulated bird nest, level area
3	Lapland butterbur, slightly raised area
4	Level area, butterbur, arctic poppies, sedge and grass
5	Small lichen-covered mound surrounded by sedge
6	Low centered polygon
7	Same as Position 6 but viewed from side
8	Simulated bird nest and lemming burrow adjacent to vehicle path
9	Simulated bird nest in center of vehicle path
10	Simulated bird nest on high centered ploygon

Live vegetation in level or depressed areas sustained very little damage as a result of multiple SEV passes. Dead, loose vegetation, however, was easily moved by the air flow and deposited along the edges of the vehicle path. Erosion of any raised microrelief was progressive with the number of passes.

Well-concealed bird nests located on a generally level terrain could survive one or two passes; the eggs usually did not survive more than a few passes without breaking. There was no visible damage to eggs in a nest a few feet from the vehicle path after 25 passes except for some dead vegetation deposited on them by the air flow. However, eggs in a nest on polygon centers did not survive even one pass without damage.

In a few cases, lemmings were inadvertently run over by the SEV but showed no visible injury, nor were their burrows and trails in level areas seriously damaged by a few passes. Small red phalarope chicks (1-day old) usually did not survive being run over, but one larger (5-day-old) chick did and showed no apparent injury. A zoologist from the U. S. IBP Tundra Biome project observed some of the tests and reported in more detail the effects of SEV operations on animal habitats.[32] His quantitative observations on the effects on vegetation due to test craft traffic are summarized in Figure 66. Dead, loose vegetation (litter) was completely removed from the vehicle path after about 50 passes; this is also evident from the corresponding increase in the amount of open area shown in Figure 66 with increasing number of passes. (The term "open area" indicates that no vegetation or litter overlies the moss mat; the sum of open area plus litter is a constant, approximately 2/3 of the total area at this locaiton). Data from Sites 1 and 2 were very similar. The moss mat at the generally level wet area (Site 1) remained undetached (although damaged and discolored) after 50 passes; the 9 percent of the moss mat removed after 50 passes at Site 2 was primarily from raised

[32]Rickard, W. E., "Ecological Evaluation of Air Cushion Vehicle Tests on Arctic Tundra of Northern Alaska," USA CRREL Research Report (in preparation).

microrelief. Sedges were generally not removed after 50 passes except on raised sections. All or nearly all lichen was removed after 50 passes at both sites. Most of the broadleaf vegetation was also removed after 50 passes except when located in depressions or troughs.

Four positions on Site 3 were selected for observations of skirt-contact effects:

Position	Location
1	At the water-land interface
2	20 to 40 ft inland from the water-land interface
3	40 to 60 ft inland from the water-land interface
4	A narrow stream, one shore covered with snow

No noticeable signature could be observed from the ground at the first three positions after one pass, but the signature could be identified after 10 passes and was very distinctive after 25 passes.

At Position 1, the progressive accumulation of water carried on shore by the vehicle skirts was evident in terrain depressions. Some degradation of the vegetation (moss mat) from skirt contact and water could also be observed. Discoloration of the area resulted when removal of some moss and lichen exposed the underlying dark organic soil. The effect was less noticeable at Position 2 although discoloration and matting of the wet vegetation into the surface could be observed. Discoloration was still evident at Position 3 and there was some dislodging of sedge clumps.

Comparison of these results with those from Sites 1 and 2 indicates once again that, at least usually, the effect of the test craft was more pronounced (reorientation of the vegetation and general discoloration of the vehicle path by matted vegetation) on wet surfaces and on surfaces wetted with water spray than on relatively dry surfaces.

At Position 4, there was no noticeable erosion on the entry side of the stream; however, the thin, loose snow cover was blown off during the first pass. The exit side of the stream was covered with a few inches of snow; any erosion or degradation was confined to the snow cover, and part of this cover remained in place after 25 passes. Ordinarily, most of this snow would have been removed during several passes over dry terrain. In this case, however, the skirt of the vehicle carried or dragged some water onto the snow-covered shore and caused considerable wet packing. The depth of the snow cover was approximately halved by skirt drag, but apparently the cover was too wet and heavy to be blown away by cushion air flow.

Operations in high-centered polygon areas resulted in progressive degradation of the polygon tops with increasing number of passes. Although one pass did not produce an easily identifiable signature, 10 passes did; the definite trail produced after 25 passes was characterized by eroded polygon tops. The trail was even more obvious because of skirt drag marks on the snow in the troughs between the polygons.

Visual evaluation of these effects are not feasible because (1) cloudy overcast conditions resulted in poor contrast in the photographs and (2) the before-and-after pictures were not taken from the same location.

Since the extent to which the various types of vegetation would be removed is significantly affected by very small changes in the air gap between the skirt fingers and the terrain surface, no reliable conclusions can be made regarding the degree of damage to vegetation due to skirt contact by the craft.

To summarize: when discussing the effects of SEV operations on organic terrains, the following three characteristics have to be considered: the vehicle, the manner in which it was operated, and the terrain over which operations occurs. Each constitutes a specific set of parameters.

1. Vehicle Characteristics. Any SEV will have properties which disturb a terrain surface: the cushion pressure, the escaping air flow from below the craft skirts, and the contact between the skirt and the terrain. In the case of the 10-ton SEV utilized here, the effect on vegetation from the *cushion pressure* (0.2 psi) itself was of no detectable consequence.

Air Flow (70 to 120 ft/sec) removed some loose, dead vegetation from tundra surfaces and virtually all of it was gone after 50 passes. The air flow caused no apparent damage, (such as detachment of sedge or grass blades, moss, leaves or blossoms) to live vegetation.

The effect of *skirt contact* was considerably more serious. The air gap between skirt and terrain was low; in fact it was vertually nonexistent below the rear bags. Repeated traffic caused progressive degradation of the organic terrain primarily from the wearing strakes on the rear bags.

2. Operational Characteristics. For the same SEV weight and air gap characteristics, three operational characteristics affect the resultant appearance of an organic terrain surface: the number of passes, the speed of the vehicle, and to some extent the direction of travel relative to the location of the sun.

The effect on organic terrains was strongly related to the *number of passes by the craft*. Although visual observations seemed to show that the degree of degradation was proportional to the number of passes, other indications based on vegetation counts showed that the degradation per pass may have slowed down with increasing number of passes. In other words, 10 passes do not necessarily cause twice the damage of five passes nor are 20 passes twice as bad as 10 passes. It was generally not possible to state explicitly the effect of a specific number of passes on organic terrains because the effect varied with such characteristics as the type of vegetation, water content, and microrelief. These characteristics would have to be discussed separately for each type of terrain. Since degradation was caused mainly by skirt contact, it is evident that the significance of the number of passes as a parameter would decrease for a higher air gap.

The effect on vegetation lessened with a decrease in test craft speed because the impact force of the skirt against vegetation or terrain microrelief decreased correspondingly. More degradation was observed at speeds of 30 to 40 mph than at 10 mph for the same number of passes. No visible effect was produced during prolonged hovering except that some of the dead, loose vegetation was removed. It is again evident that the significance of speed as a parameter would decrease with an increase in the air gap (decreased skirt contact).

The signature of the test craft path on wet tundra, specifically the color shade relative to the surrounding undisturbed terrain surface, depended on the *direction of travel*. The rear bags bent the wet vegetation in the direction of travel. Thus when the craft was traveling away from the sun, the lighter underside of

live vegetation was exposed to the sun but when the craft was traveling into the sun, the vehicle path appeared darker than the surrounding terrain surface. This was not apparent on dry vegetation. Consequently, the change in albedo of the vehicle path on wet tundra depended to some extent on the direction of travel; however, this effect, would also lessen with an increase in the air gap, especially under the rear bags. After repeated passes, the total effect of degradation from skirt contact outweighed any effect due to the direction of travel.

3. Terrain Characteristics. Three parameters are of major significance in describing the characteristics of organic terrains; the vegetative features of the organic mat, the water content, and the microrelief. The damage inflicted on organic terrains by ACV operations depends somewhat on the *vegetative features* of the organic mat, i.e., their morphological and anatomical features and the species composition. Mosses were less resistant to skirt abrasion than were sedges or grasses, and stiff vegetation was damaged more easily than soft or pliable vegetation.

The signature left by the SEV was more apparent in areas of high *water content* than in dry areas. This was particularly evident after one or a few passes; the difference was less apparent after repeated passes. Although the one and five-pass signatures left by the craft were more prominent on wet than on dry tundra, the difference indicated by immediate visual appearance may not necessarily be an indication of a difference in the ultimate long-range effect. A comparison of the botanical observations on wet and dry tundra after the test craft traffic showed no significant variations between the two areas. The change in albedo due to the direction of traffic was noticeable on wet but not on dry tundra. (A report by Bellamy et al.,[33] on the effect of water content on the impact of tracked vehicle traffic for Arctic organic terrains indicated that although the wettest terrains sustained the greatest immediate damage, the long-term regeneration of the vegetation was more efficient in the wettest terrains).

Microrelief appeared to be the terrain characteristic with the most significance for degradation of the organic mat. Vegetation on level ground or in depressions could survive 50 passes of the test craft but this same type in raised areas was removed during the first pass. Erosion of any raised microrelief was significantly more serious than for level terrain. High centered polygons sustained the most damage due to skirt drag.

Conclusions on the apparent effects of SEV traffic on organic terrains also depended on the position of observation. During inspection at close range, for example, foot marks on wet tundra were much more obvious than the passage of a SEV over that same particular spot. Yet this same, almost imperceptible SEV path became a very evident and distinct signature when viewed from an aircraft. It was almost a matter of "the closer you look, the less you see." It was quite a surprise, for example, to see so many Weasel tracks on the aerial photographs; many of them were completely unnoticed by the ground observers.

[33] Bellamy, D. et al., "1971 Terrain Traffic in Tundra," Nature, Vol. 231 (18 Jun 1971).

A definitive evaluation of the effects of SEV operations on organic terrains can be accomplished only by a quantitative approach (e.g., Figure 66), such as determination of changes in the thermal conductivity and albedo and the resulting effects on the depth of thaw of tundra or the ultimate changes in the natural propagation and growth habits of the vegetation. Moreover, what actually consitutes "damage" to the organic terrain may not be readily definable, nor may any and all changes to the organic terrain result in permanent damage. Long-term monitoring of the various test sites, especially at Barrow, is required in order to fully evaluate the ultimate impact of SEV operations on organic terrains.

CONCLUSIONS AND RECOMMENDATIONS

1. The 1971 test program demonstrated the feasibility of an SEV for operation in an Arctic environment. Accordingly, the development of the prototype for a large SEV should be encouraged. However, before the related test program is conducted in the Arctic, the performance capabilities of any future large SEV should be completely documented at a test range within the continental United States. The test range to be used for builders' trials and engineering tests should be selected early in the design stage to ensure the availability of appropriate facilities (service apron, personnel quarters, shelters for maintenance items, etc.).

2. The need for long-range integrated logistic planning in support of any operation in the Arctic cannot be overemphasized. Important (typical) long-lead tasks, special equipment, and required facilities for an Arctic test range are identified below:

a. A trials director with responsibility for planning the test agenda, selecting data acquisition equipment, and planning and implementing the test program should be designated in the early design stages of an Arctic SEV.

b. The extent and type of engineering testing programs should be determined early in the design to facilitate location and installation of the required transducers, wiring, etc. on the SEV.

c. An Arctic SEV should be equipped with standard aircraft communications equipment including aircraft emergency beacons. In addition, all crew members should be issued portable aircraft emergency beacons.

d. The data acquisition system for any future test program should incorporate the latest available technology for airborne recording and be designed to IRIG specifications in order to conserve space, reduce weight, etc.

e. A portable test facility should be provided to ensure complete calibration capabilities and economical data-recording techniques for all proposed radar units.

f. Air-transportable shop facilities equipped with parts, materials, and tools should be available to service each subsystem of an SEV.

g. Portable shelters, rations, communications equipment, firearms, etc. should be provided for all personnel aboard the craft, regardless of the duration of any planned Arctic trial.

h. The skill and experience of the civilian operator contributed immeasurably to the success of the 1971 trials. It is recommended that the background of SEV operators for future trials either in CONUS or the Arctic be similar to that of the traditional test pilot. It is further recommended that all operators for Arctic trials be required to have at least 100 hr of actual experience in an SEV.

3. Experimental determination of the physical properties of the SEV was found to be an involved and expensive process. Accordingly, it is recommended that reliance be placed on appropriate analytical methods for determining such physical characteristics as moments of inertia for large future SEV's.

4. The experimental determination of longitudinal and torsional bending of the craft involved bulky weights and coupling support systems. Accordingly, consideration should be given to using scaled tests and computer techniques for such structural analyses.

5. Protruding ridges on ice and depressions in tundra looked deceptively flat until the craft was almost upon them. Despite the skill of the operator, there was one occasion on which the SEV slid into a tractor trail and required assistance to remove and other occasions when hard impact with pressure ridges damaged the under side and lateral stability bags. Inasmuch as the craft was designed and constructed to operate over water, its performance over the many difficult terrains and obstacles encountered during the trials was a significant indication of its adaptability to the Arctic environment. It is recommended that criteria be developed for a test course to measure the response of a large SEV to a random terrain.

6. There was a marked difference in the effectiveness of the three candidate sensors used to detect obstacles and their special features are given below:

a. The azimuth beam width of the 10-gHz radar system was too wide for shadow processing, and dynamic range limitations in the analog recording system were not compatible with effective shadow processing.

b. The 94-gHz radar showed great promise for Arctic use. Returns from obstacles in the test area were well above the noise, and sensor performance was not noticeably degraded in the fog conditions experienced during the tests (visibility down to 1000 ft). It is recommended that a more complete 94-gHz system be developed and tested in the Arctic with an improved data-recording capability and also that more detailed propagation data be developed at 94 gHz.

c. A 1.06-micron sensor can be developed to meet the Arctic obstacle detection objective in clear weather, but it will not operate effectively in even a light fog. More detailed propagation data should be developed at both 1.06 and 10.6 microns. If as anticipated, the 10.6-micron wavelength has a significant weather advantage, a test program should be initiated to determine the character of radar returns from ice and snow at this wavelength.

7. After an obstacle had been traversed, the accelerations at the craft bow and center of gravity were very similar in magnitude and phase, indicating a predominately heave rather than pitch motion. The natural frequency of the vibration in heave was approximately 1.0 Hz as determined by acceleration and pressure waveforms.

8. Hull vibration measurements with the craft tethered showed that its machinery excited the SEV primarily at blade and twice blade frequencies. Vibration levels were higher at the stern and may account for the many difficulties experienced with the stern-mounted velocity sensor. There were differences in the accelerations and forces measured with the craft tethered and while underway, and these differences warrant a detailed examination. The presence of highly nonuniform wakes into the propeller and large lateral propeller bearing forces must be taken into account when designing propeller mounts, shafts and seals for future SEV's.

9. Both the method of propeller pitch reversal and the method of craft reversal with maximum positive propeller pitch required large distances for decelerating and stopping the craft. Accordingly, other methods should be investigated, e.g., auxiliary power, ground contact devices, etc. Moreover, an improved analytical method should be developed to predict the deceleration and stopping characteristics of projected large Arctic SEV's.

10. For the same compressor-turbine RPM, throttle position, and propeller pitch setting (i.e., approximately the same power), the craft traversed unprepared snow at a lower velocity than prepared snow and took longer to traverse a polygon hard surface than one of natural tundra.

11. Pilot-induced yaw oscillation is not considered a problem for the craft used in the trials. However, at higher speeds, an operator may have difficulty in maintaining directional control of a craft that has marginal directional stability and that does not have control augmentation.

12. In support of marginal ice zone studies by University of Washington scientists, the craft operated under extremely difficult conditions and provided a capability for scientific data collection that would not have been possible even with a helicopter. It also proved very valuable for logistic support.

13. An estimate of the effects of SEV operations on organic terrains requires consideration of the vehicle characteristics (cushion pressure, escaping air flow from below the skirts, and skirt-terrain contact), the manner in which it is operated (number of passes, speed, and direction of travel relative to the direction of the sun), and the terrain over which it operates (vegetative content of the organic mat, water content, and microrelief). Skirt-terrain contact was by far the most significant factor. Periodic monitoring, including on-site inspections, should be conducted in order to determine the long-term impact of the trials.

14. A definitive evaluation of the effects of SEV operations on organic terrains can be achieved only by a quantitative assessment of changes in the albedo and thermal conductivity of the terrain and, in the case of the tundra, the resulting effect on the depth of thaw and the ultimate changes in the natural propagation and growth habits of the vegetation.

AREAS FOR FUTURE STUDY

As a result of having conducted these field tests, additional research is needed in the areas of communication, navigation, station keeping, detection and avoidance of obstacles, maintenance techniques, operational procedures, and logistic support. A reliable craft-to-shore communications system is considered an absolute

necessity for any future SEV Arctic operation. Moreover, further efforts are needed to develop a reliable craft velocity meter, a lighter weight data acquisition system with improved data recording capability, criteria for a representative test course, better methods for decelerating and stopping and an improved analytical technique for predicting these and other maneuvering characteristics of the projected large Arctic SEV, a more complete 94-gHz sensor system and the collection of more detailed propagation data at 94 gHz and 10.6 microns, and quantitative methods and techniques to evaluate the long-term effects of SEV operations on organic terrains.

ACKNOWLEDGEMENT

The authors wish to acknowledge the technical and administrative support of Mr. William F. Barnett during the writing of this report.

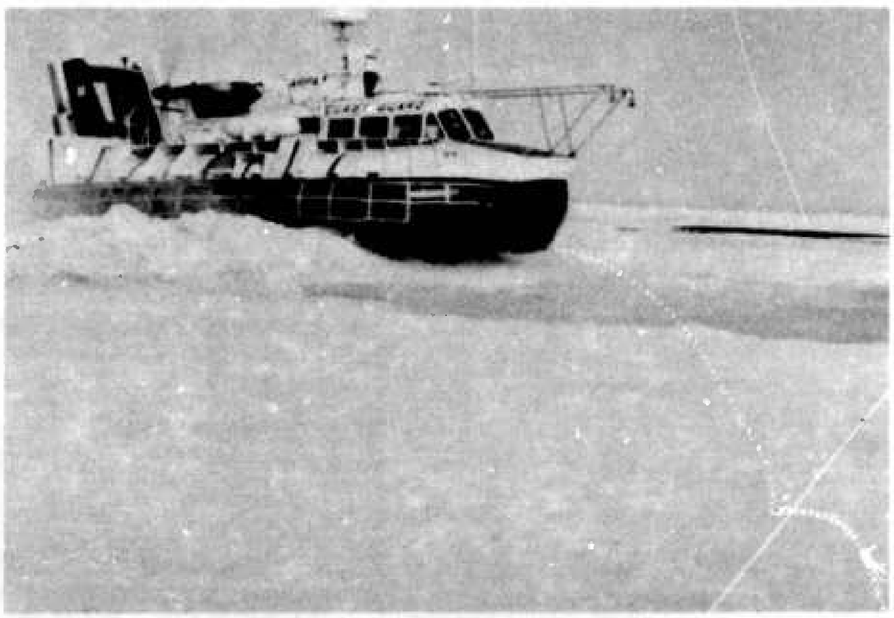


Figure 1 – Test Craft for 1971 Arctic Trials

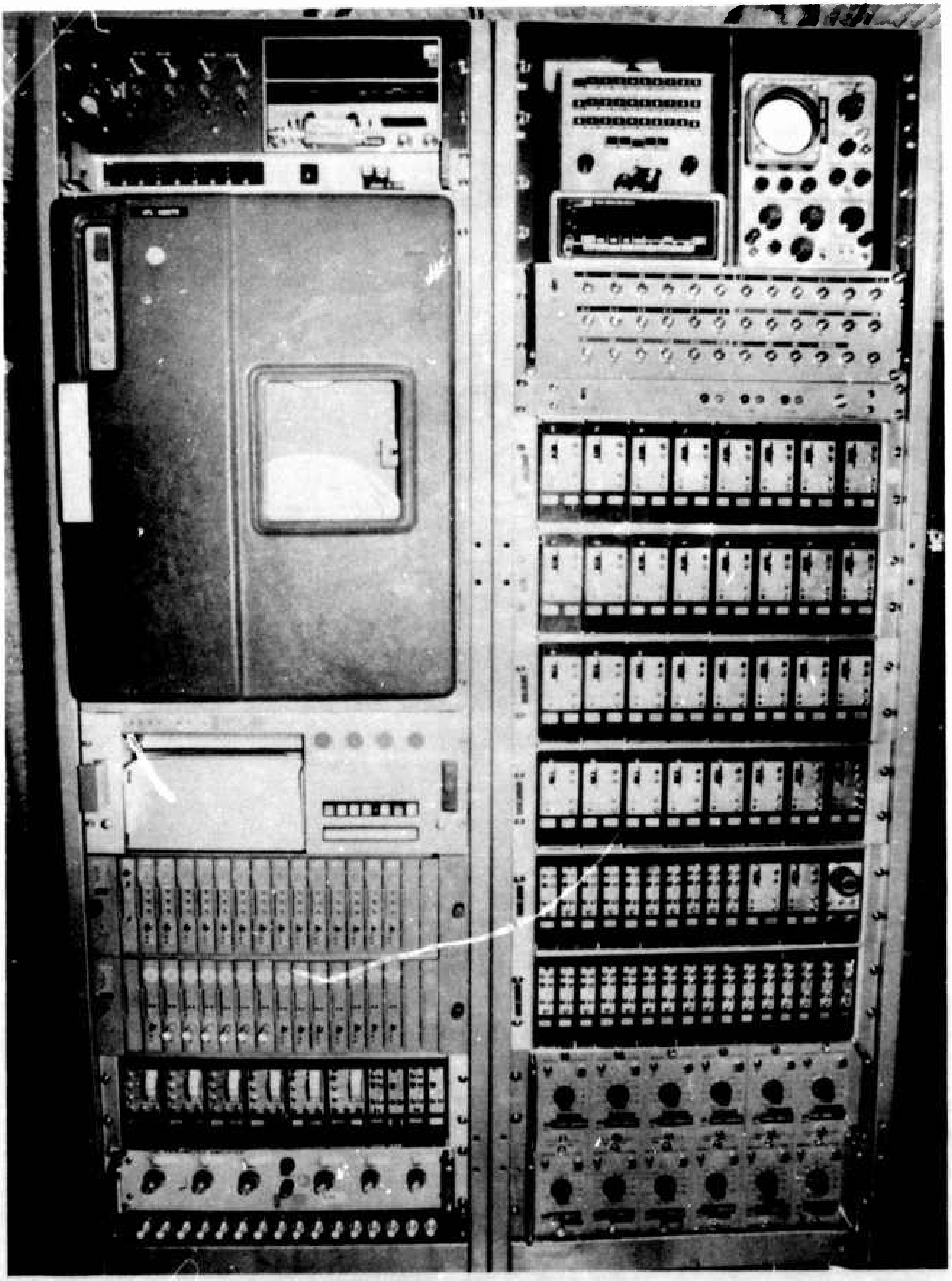


Figure 2 – Data Acquisition System

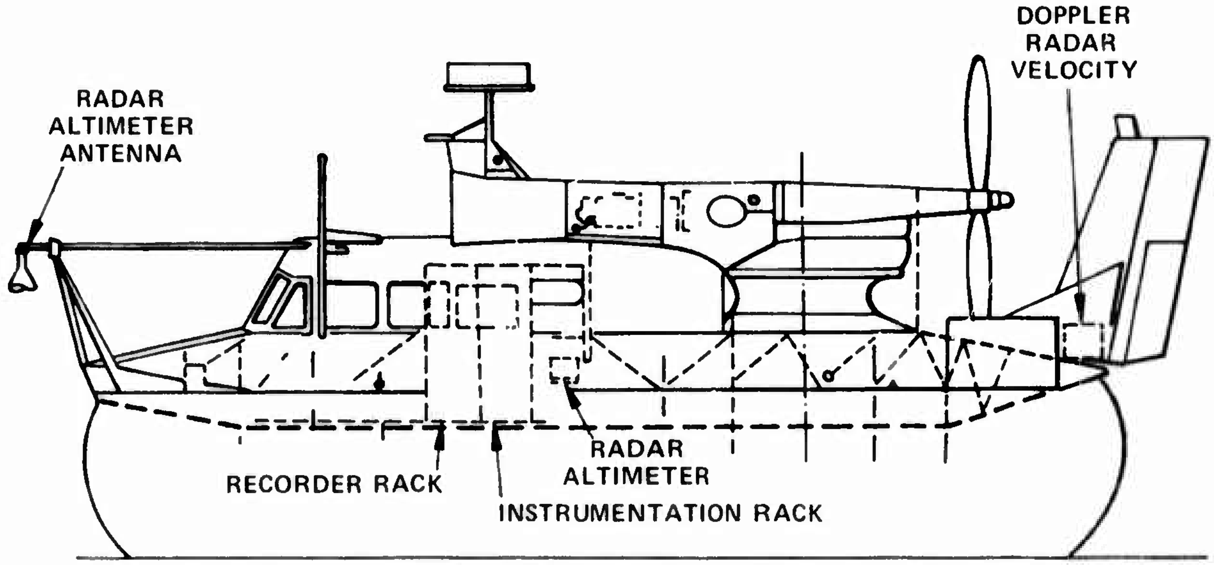


Figure 3 – Location of Data Acquisition System on Test Craft

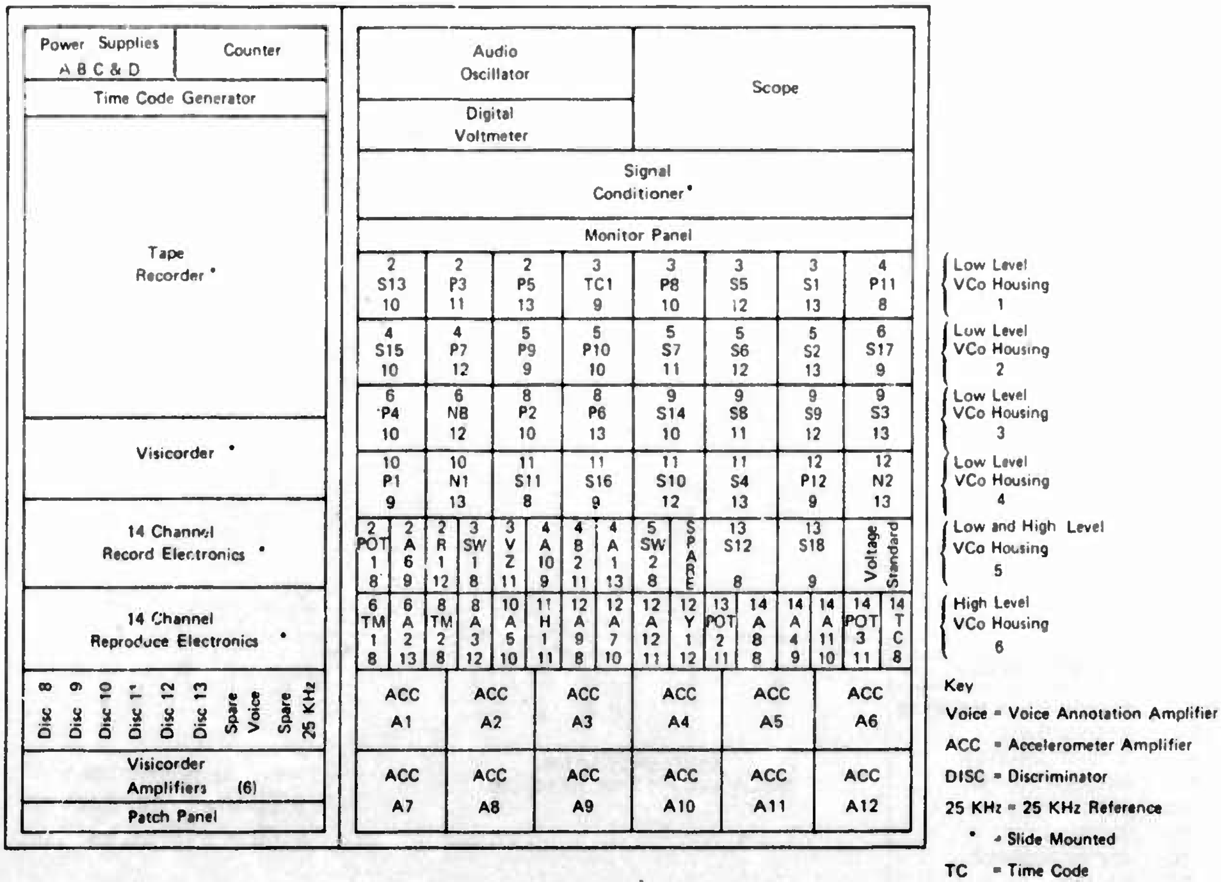
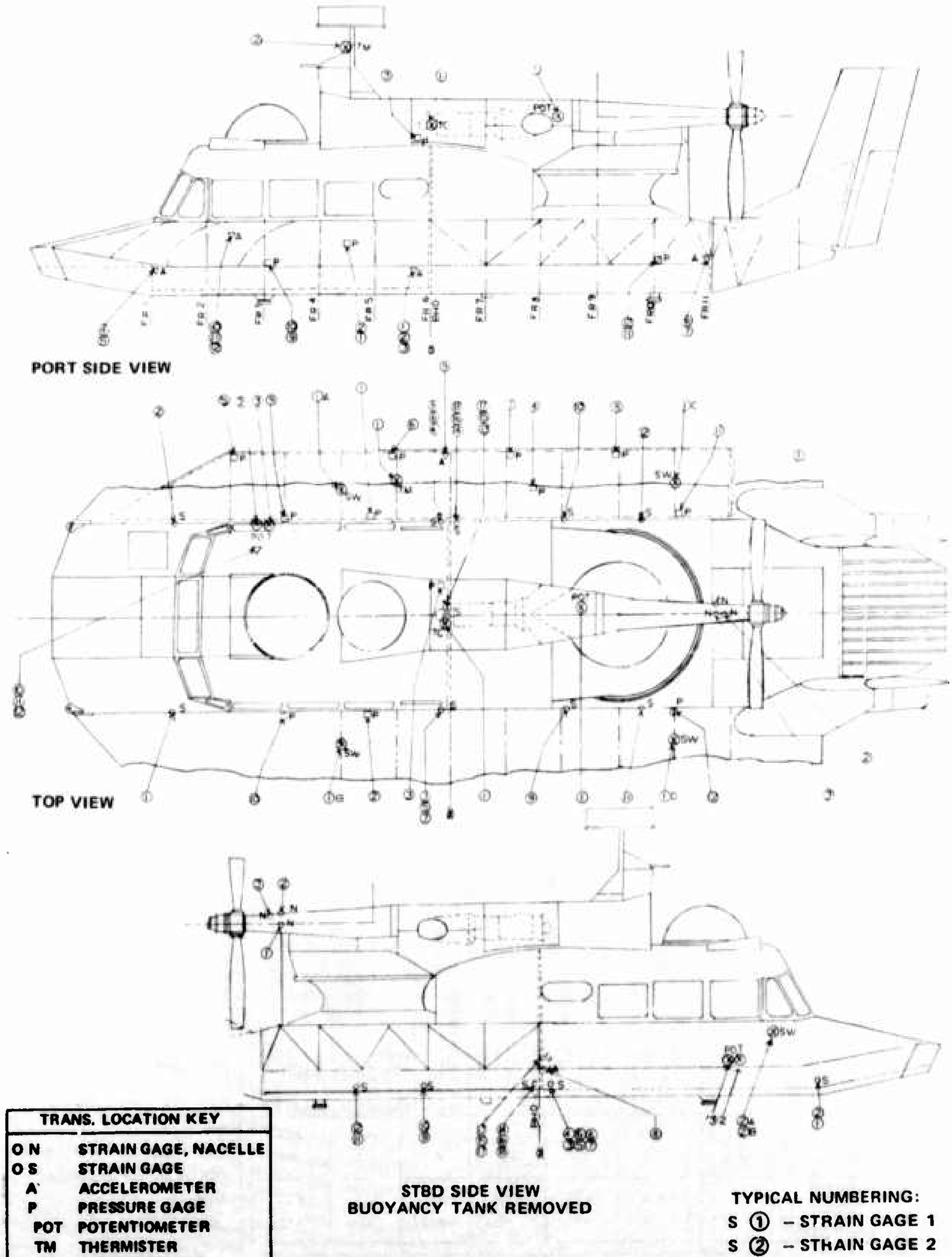


Figure 4 – Rack Layout for Data Acquisition System



TRANS. LOCATION KEY	
O N	STRAIN GAGE, NACELLE
O S	STRAIN GAGE
A	ACCELEROMETER
P	PRESSURE GAGE
POT	POTENTIOMETER
TM	THERMISTER
TC	THERMOCOUPLE
SW	SWITCH
R	TACH GENERATOR
H	HEIGHT SENSOR
V	VELOCITY SENSOR

Figure 5 – Location of Transducers on Test Craft

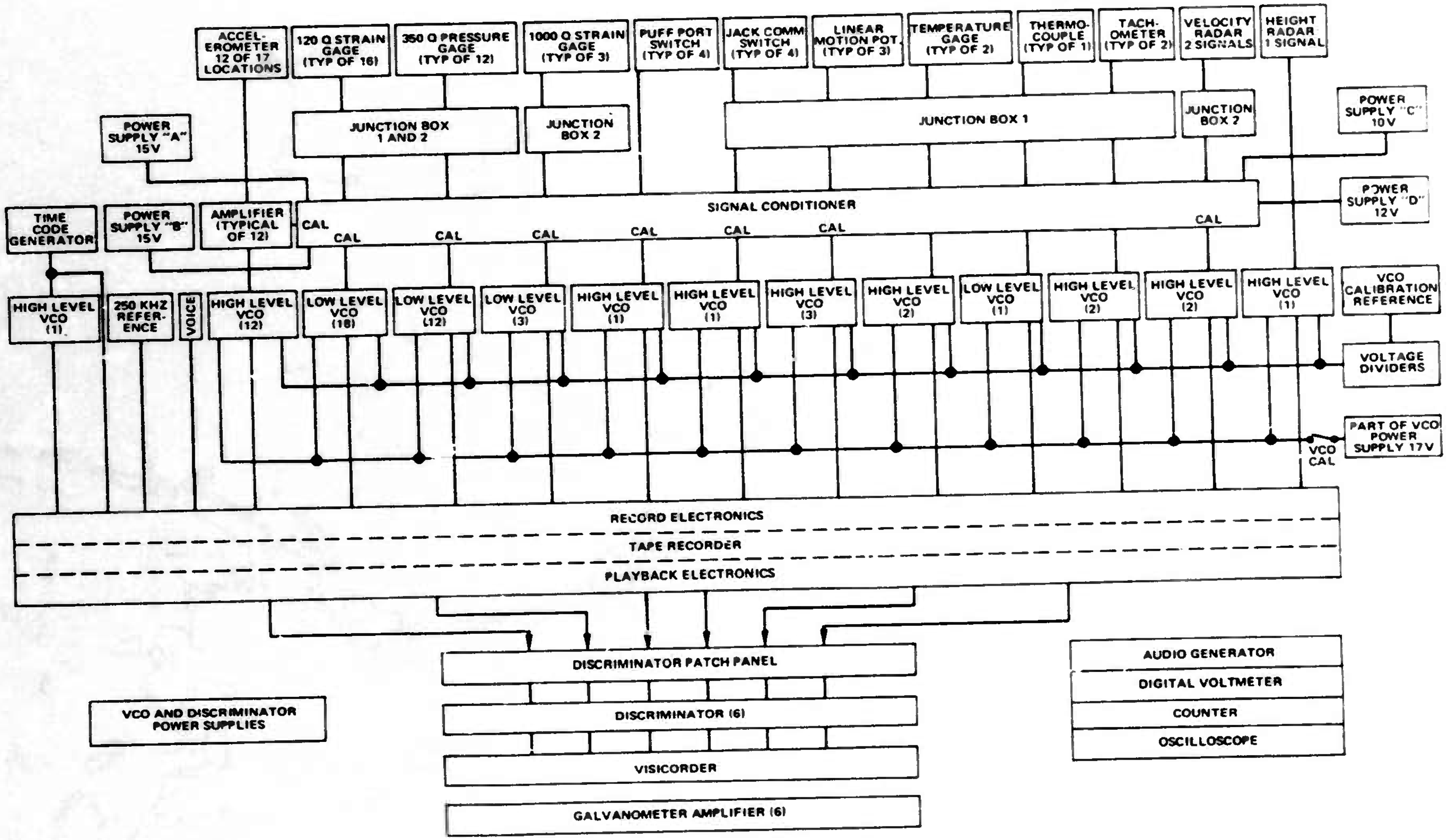


Figure 6 – Details of Data Acquisition System

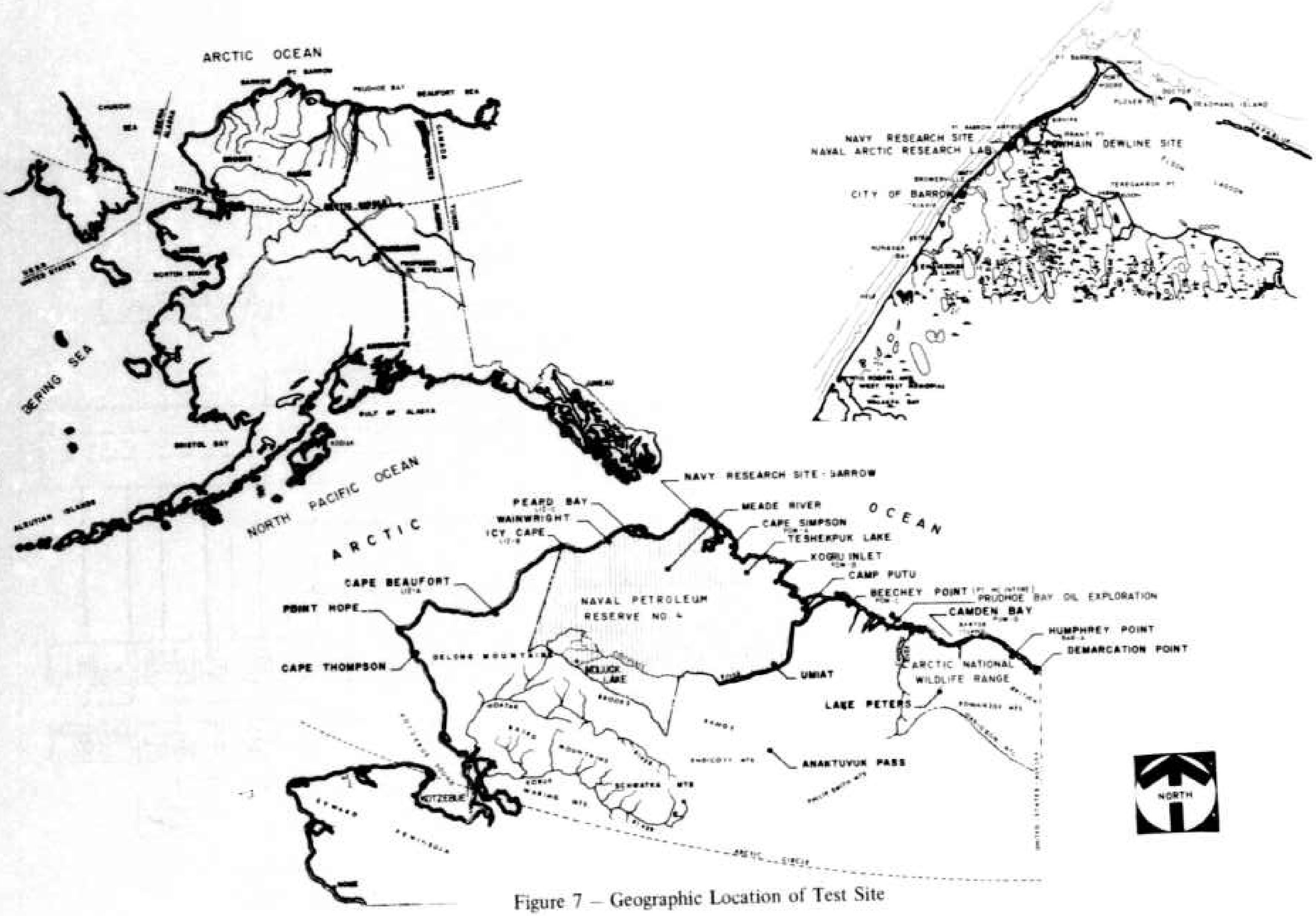


Figure 7 – Geographic Location of Test Site

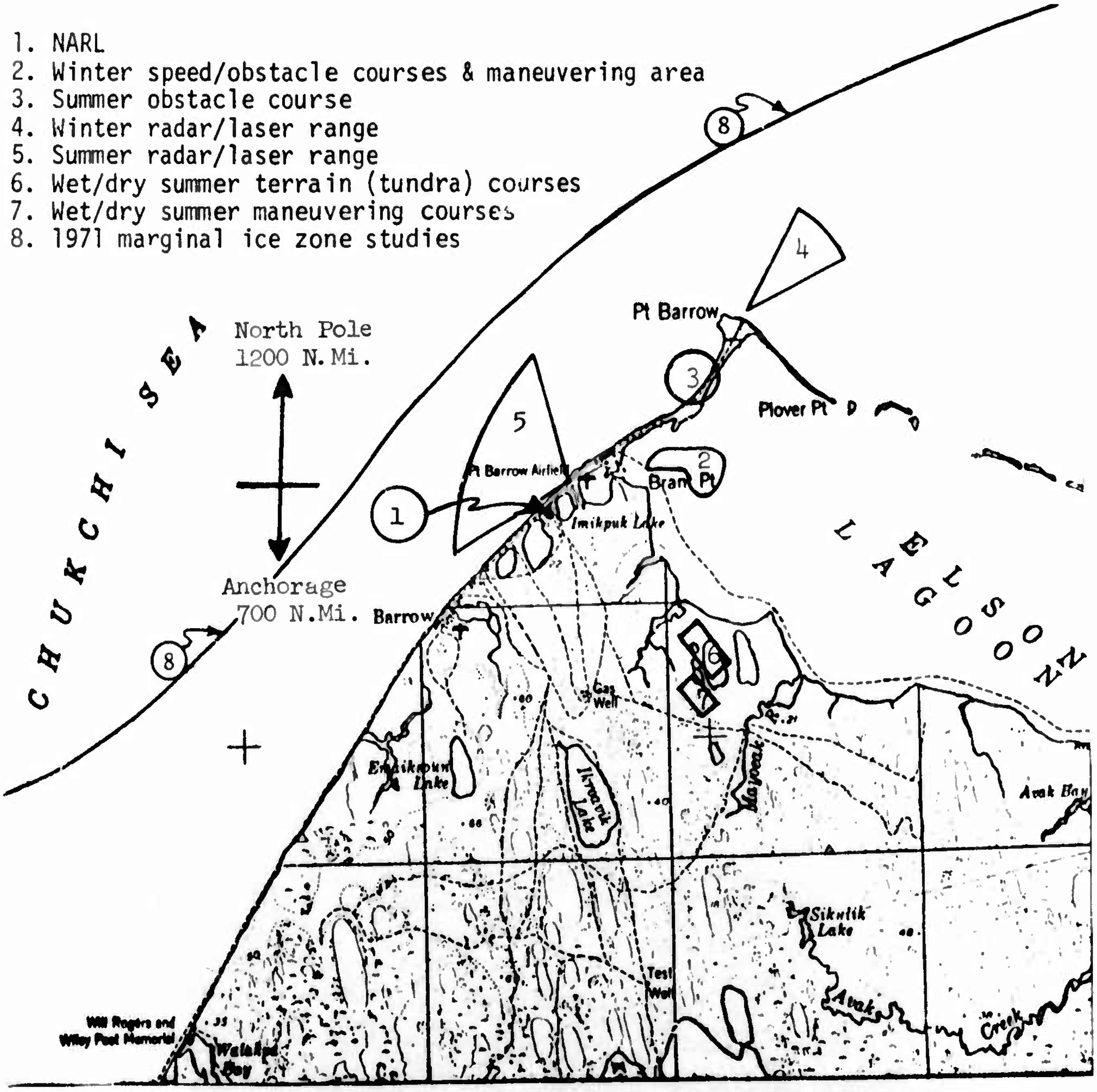


Figure 8 – Test Areas for 1971 Arctic Trials

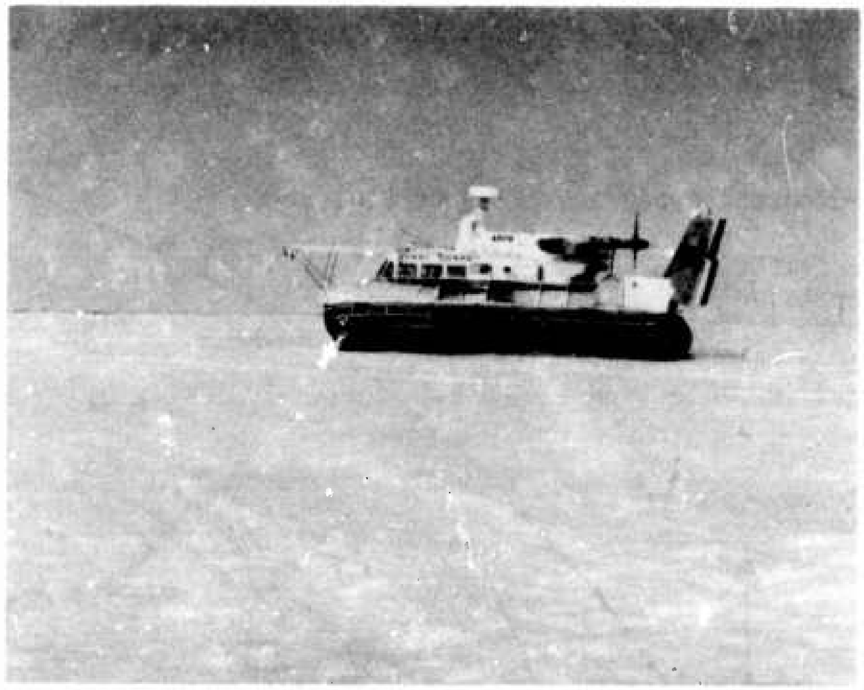


Figure 9 – Test Craft Operating on Elson Lagoon

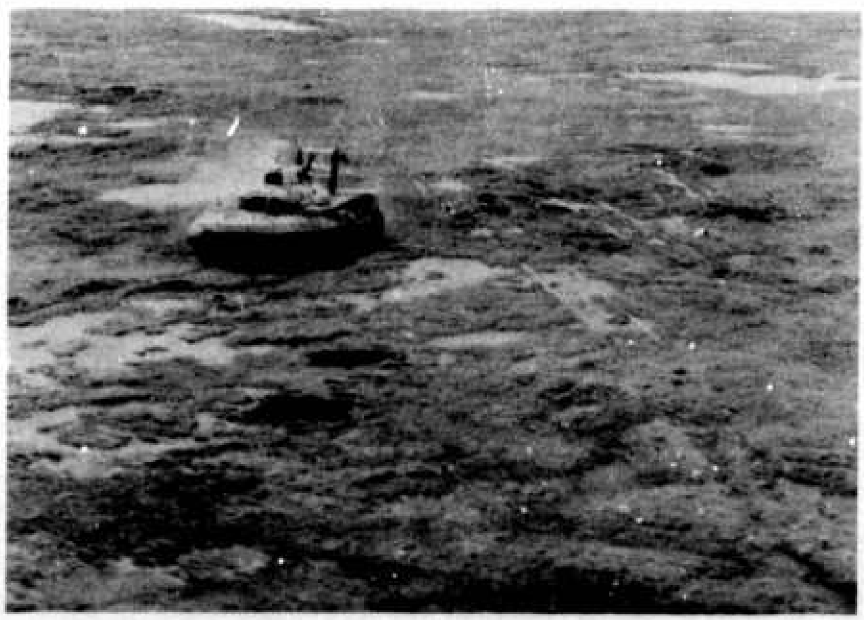


Figure 10 – Test Craft Operating on Tundra

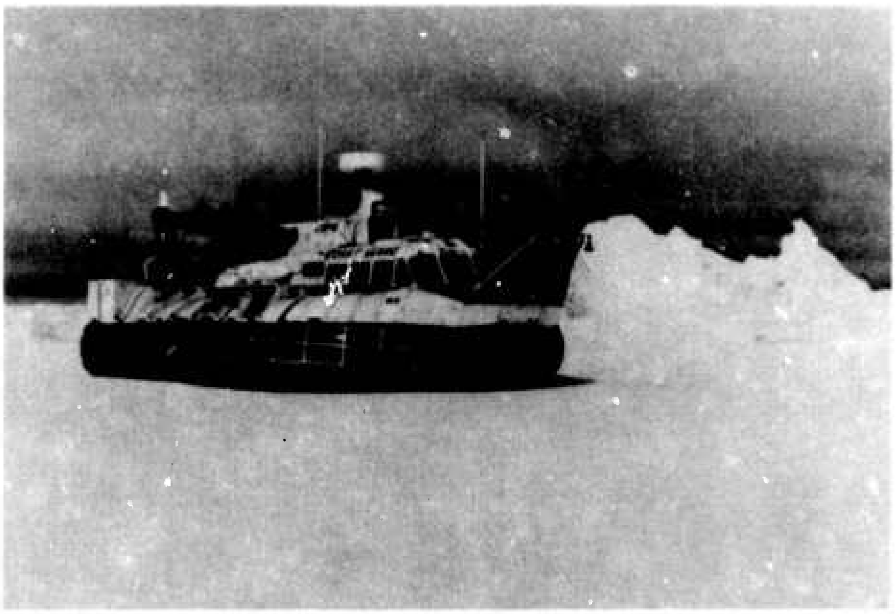


Figure 11 – Test Craft in Transit to Winter Test Course–Late May

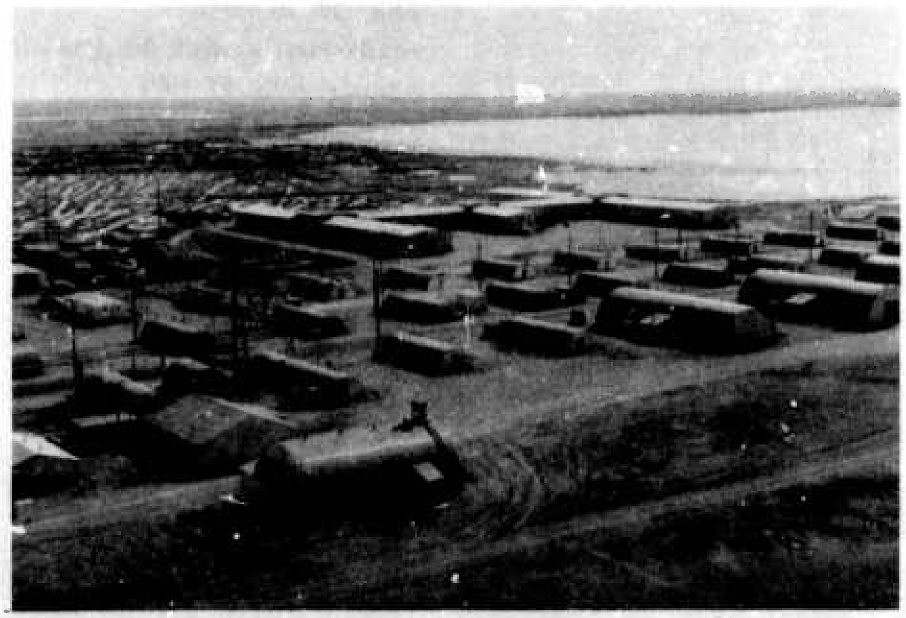


Figure 12 – Naval Arctic Research Laboratory Complex–Late June

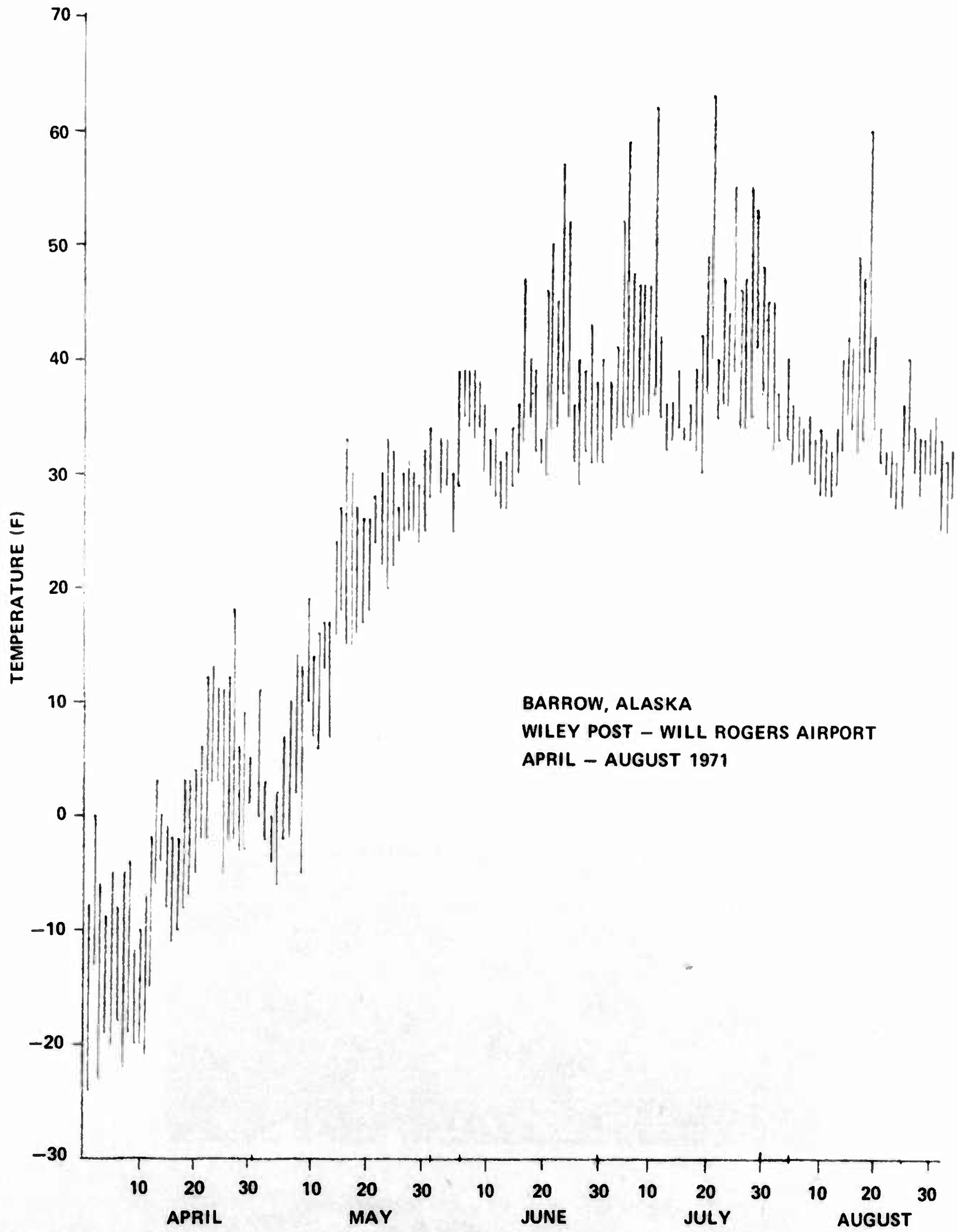


Figure 13 – Recorded High and Low Temperatures during 1971 Arctic Test Program

JANUARY							FEBRUARY							MARCH						
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
					1	2		1	2	3	4	5	6		1	2	3	4	5	6
3	4	5	6	7	8	9	7	8	9	10	11	12	13	7	8	9	10	11	OT 12	13
10	11	12	13	14	15	16	14	15	16	17	18	19	20	14	OT 15	OT 16	OT 17	OT 18	OT 19	OT 20
17	18	19	20	21	22	23	21	22	23	24	25	26	27	21	D 22	D 23	D 24	TC 25	TC 26	A 27
24	25	26	27	28	29	30	28							A 28	A 29	A 30	A 31			
31																				

APRIL							MAY							JUNE						
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
				OT 1	OT 2	OT 3							CF 1			OT 1	OT 2	OT 3	M 4	M 5
I 4	CF 5	CF 6	CF 7	CF 8	CF 9	CF 10	CF 2	CF 3	CF 4	CF 5	I 6	OT 7	S 8	I 6	OT 7	CF 8	OT 9	W 10	OT 11	OT 12
CF 11	CF 12	CF 13	CF 14	CF 15	CF 16	CF 17	S 9	I 10	I 11	I 12	S 13	I 14	S 15	M 13	M 14	M 15	M 16	M 17	M 18	M 19
CF 18	CF 19	CF 20	CF 21	CF 22	CF 23	CF 24	OT 16	OT 17	OT 18	I 19	OT 20	OT 21	I 22	M 20	OT 21	OT 22	OT 23	CF 24	CF 25	CF 26
CF 25	CF 26	CF 27	CF 28	CF 29	CF 30		23	OT 24	25	26	OT 27	OT 28	OT 29	CF 27	CF 28	CF 29	CF 30			
							OT 30	OT 31												

JULY							AUGUST							SEPT						
S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
				CF 1	CF 2	CF 3	OT 1	OT 2	OT 3	OT 4	OT 5	OT 6	OT 7				D 1	D 2	D 3	D 4
CF 4	CF 5	CF 6	CF 7	I 8	I 9	OT 10	OT 8	OT 9	OT 10	OT 11	OT 12	OT 13	OT 14	5	6	7	8	9	10	11
OT 11	I 12	S 13	OT 14	OT 15	OT 16	S 17	OT 15	M 16	M 17	M 18	OT 19	OT 20	OT 21	12	13	14	15	16	17	18
S 18	S 19	S 20	OT 21	OT 22	OT 23	S 24	OT 22	OT 23	OT 24	OT 25	OT 26	OT 27	D 28	19	20	21	22	23	24	25
I 25	M 26	M 27	M 28	M 29	I 30	31	D 29	D 30	D 31					26	27	28	29	30		

OT – OPERATIONAL TESTS
D – DISASSEMBLE CRA. T
A – ASSEMBLE CRAFT
I – TEST PREPARATION AND INSTRUMENTATION
S – NO TESTS SCHEDULED
TC – TRANSPORT CRAFT
CF – CRAFT FAILURE
M – MAINTENANCE
W – WEATHER

Figure 14 – Test Craft Operational Calendar–1971

Figure 15 – Typical Pressure Ridges off the Coast at Barrow

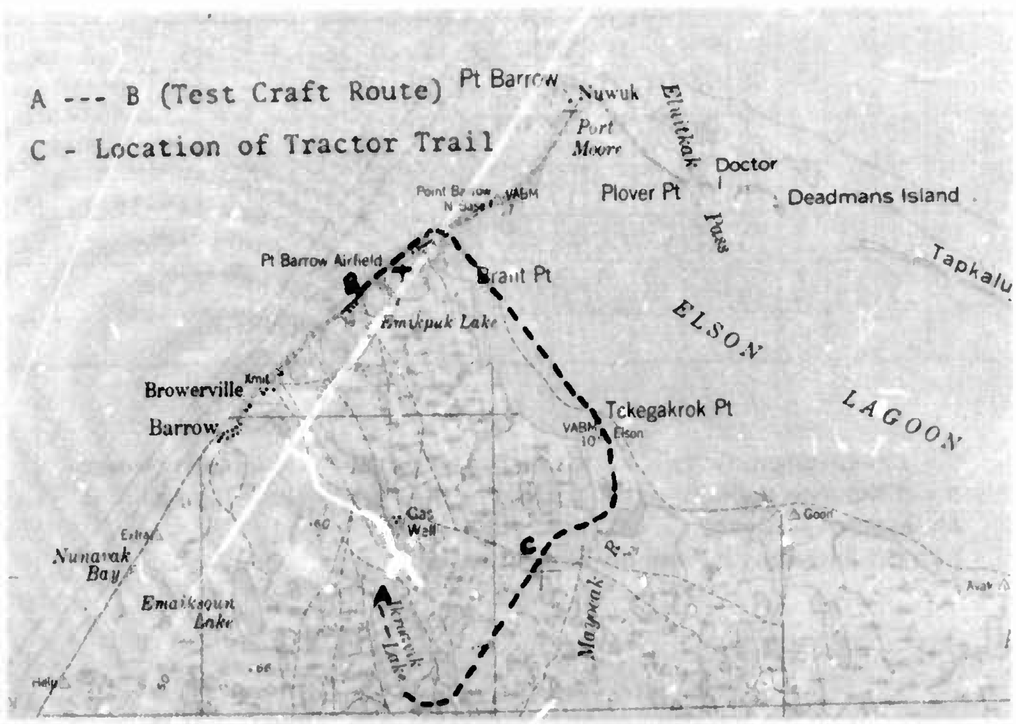


Figure 16 – Operating Route of Test Craft on Tundra

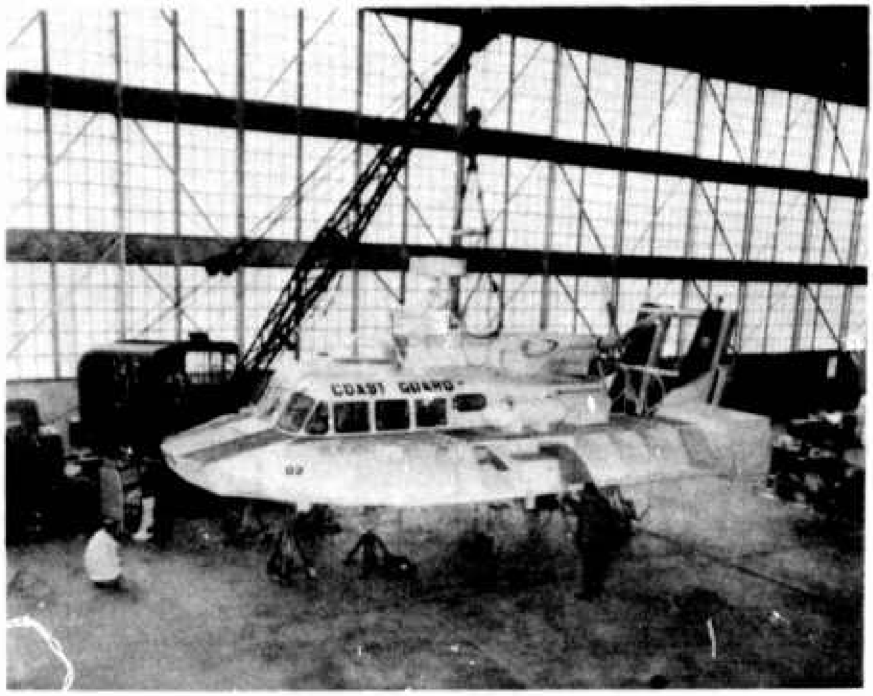


Figure 17 – Experimental Determination of Craft
Moment of Inertia

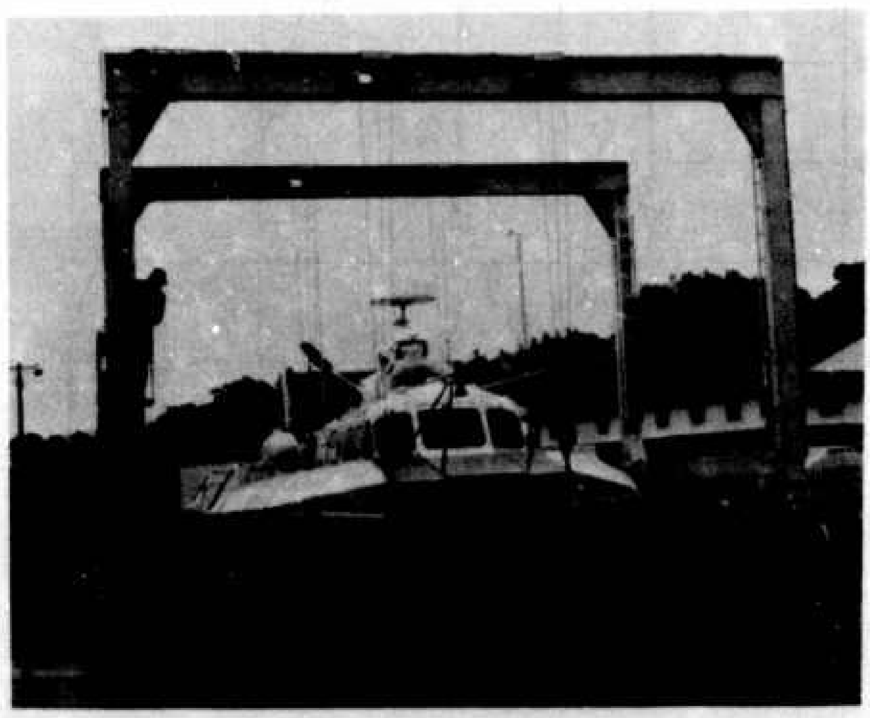


Figure 18 – Test Craft Undergoing Vibration Tests

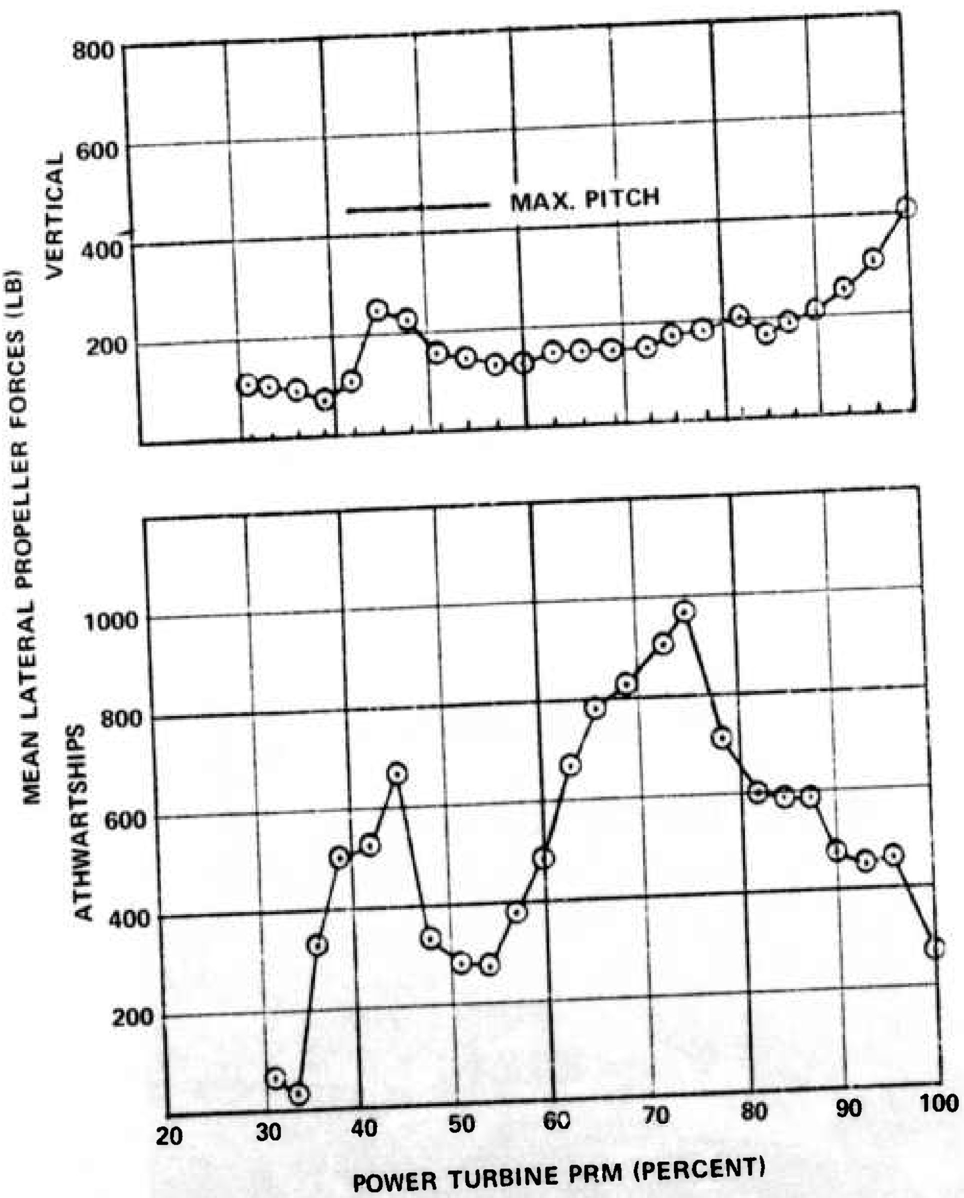


Figure 19 – Mean Lateral Propeller Bearing Forces versus Power Turbine RPM for the Tethered Craft

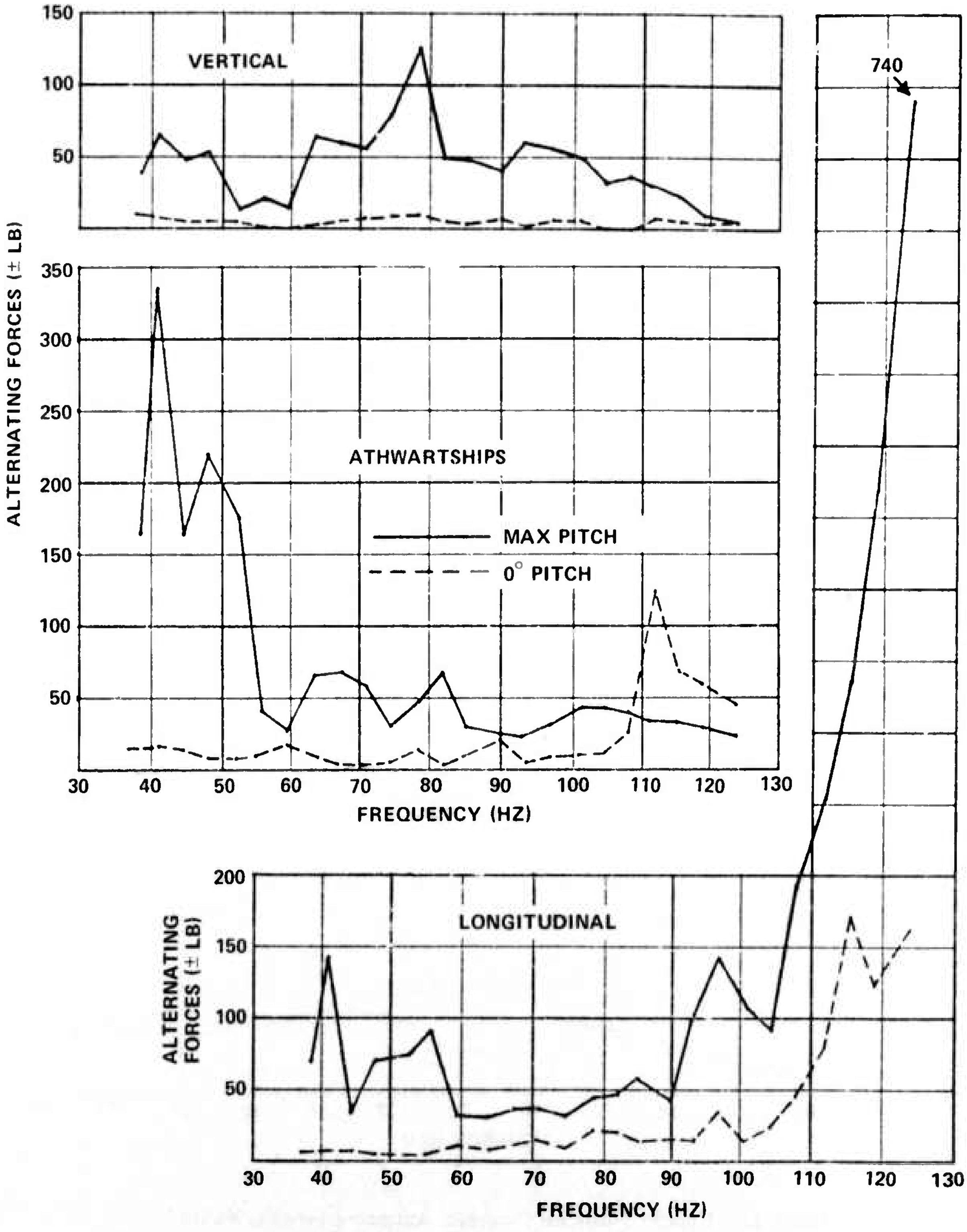


Figure 20 – Propeller Blade Frequency Alternating Forces in Nacelle versus Frequency for the Tethered Craft

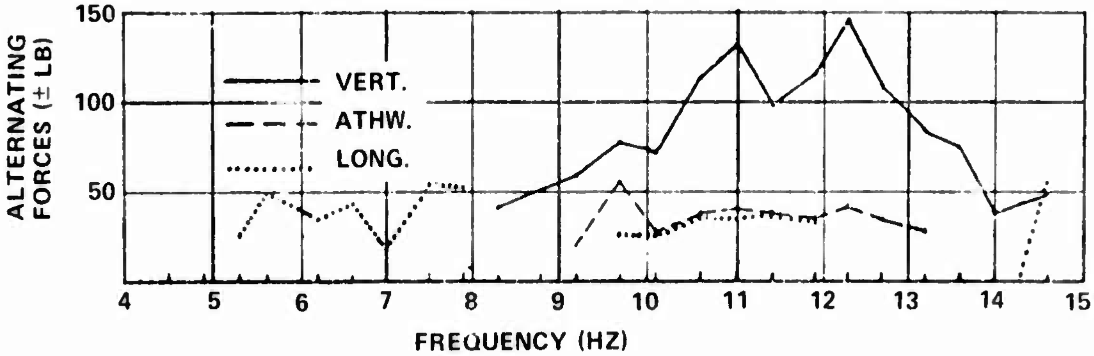


Figure 21 – Fan Rotational Frequency Alternating Forces in Nacelle versus Frequency While Tethered

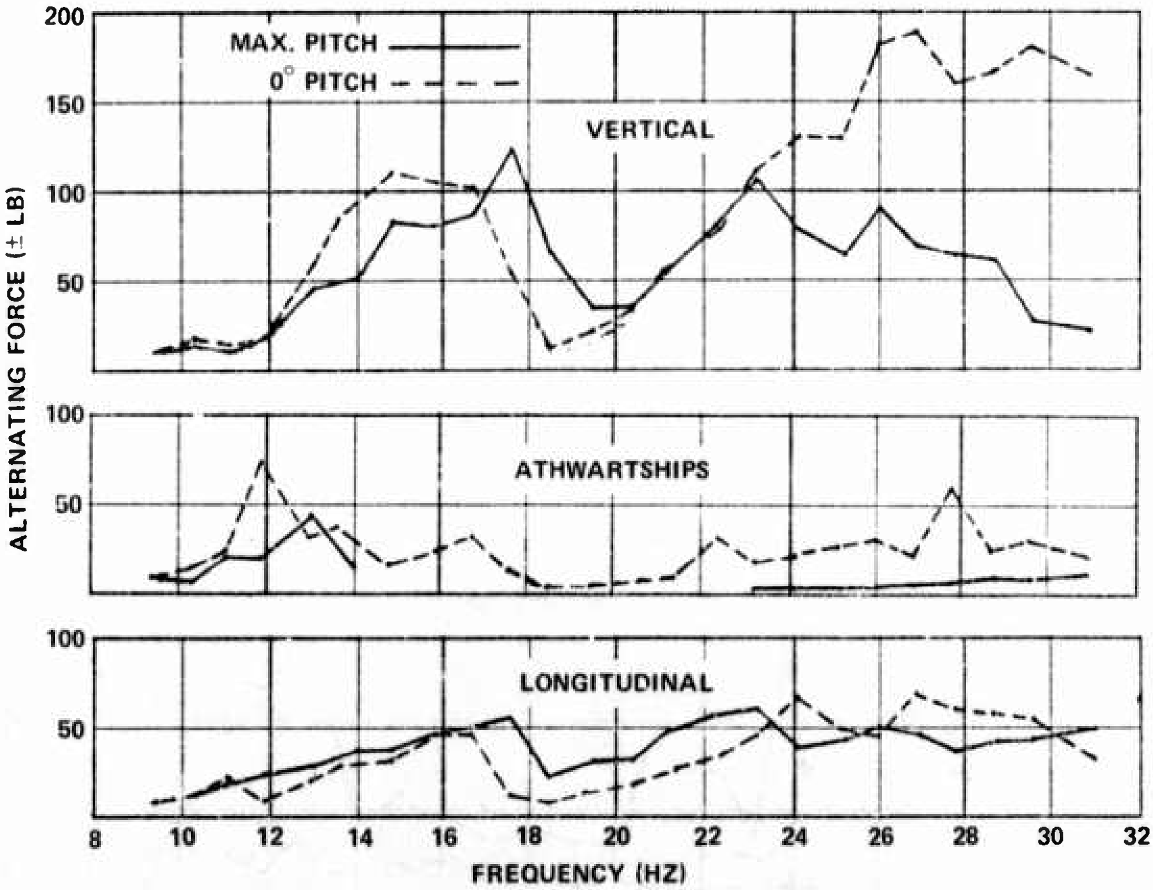


Figure 22 – Propeller Rotational Frequency Alternating Forces in Nacelle versus Frequency for the Tethered Craft

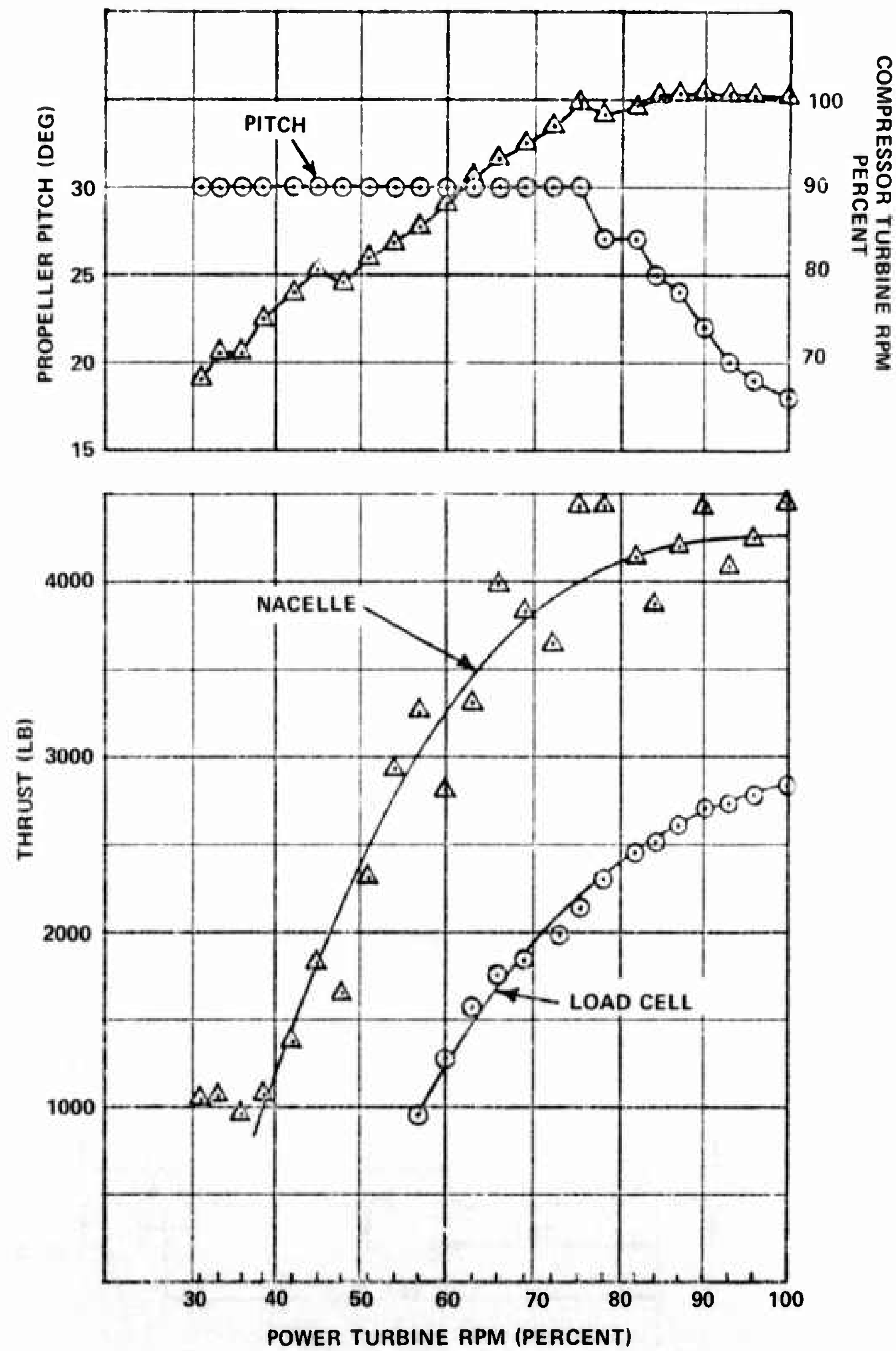


Figure 23 – Mean Thrust versus Power Turbine RPM for the Tethered Craft

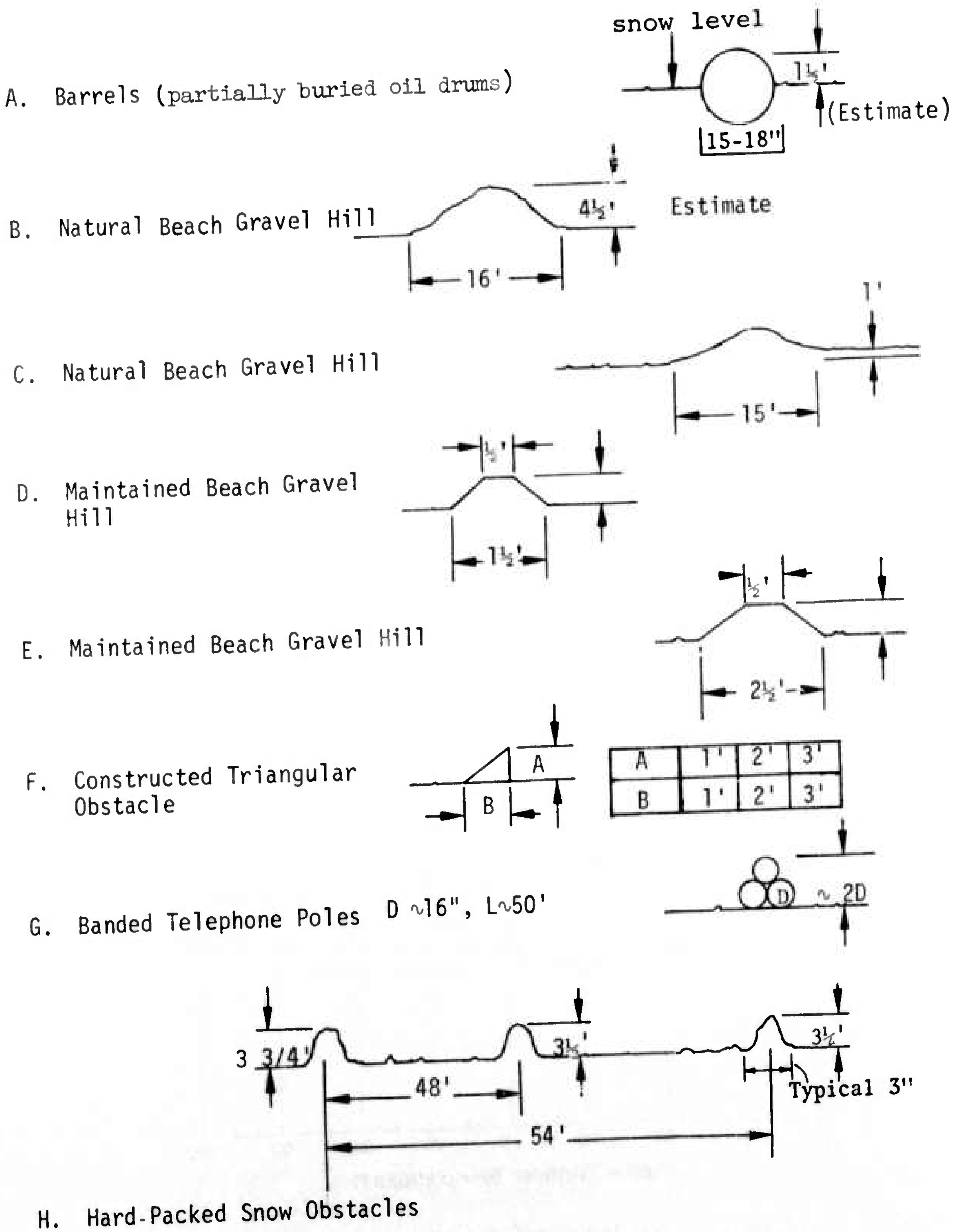


Figure 24 – Typical Obstacles Used during 1971 Arctic Test Program

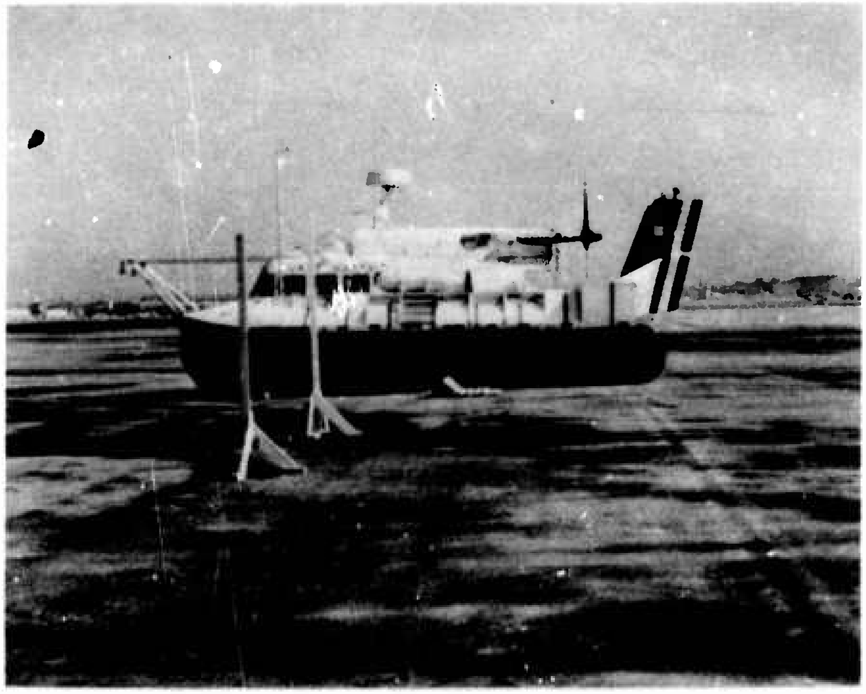


Figure 25 – Craft Crossing Small Wooden Obstacle at Alameda NAS

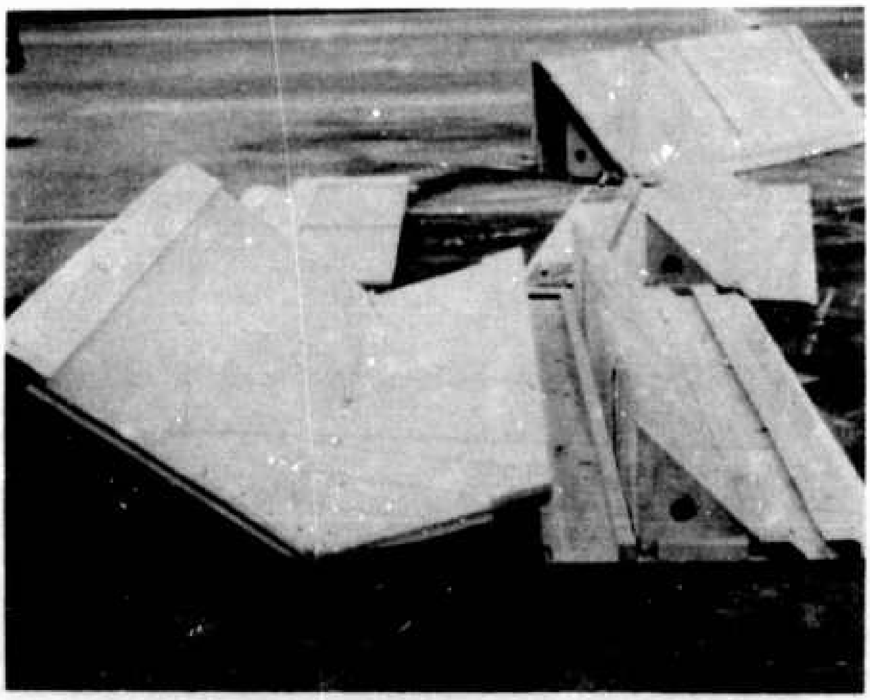
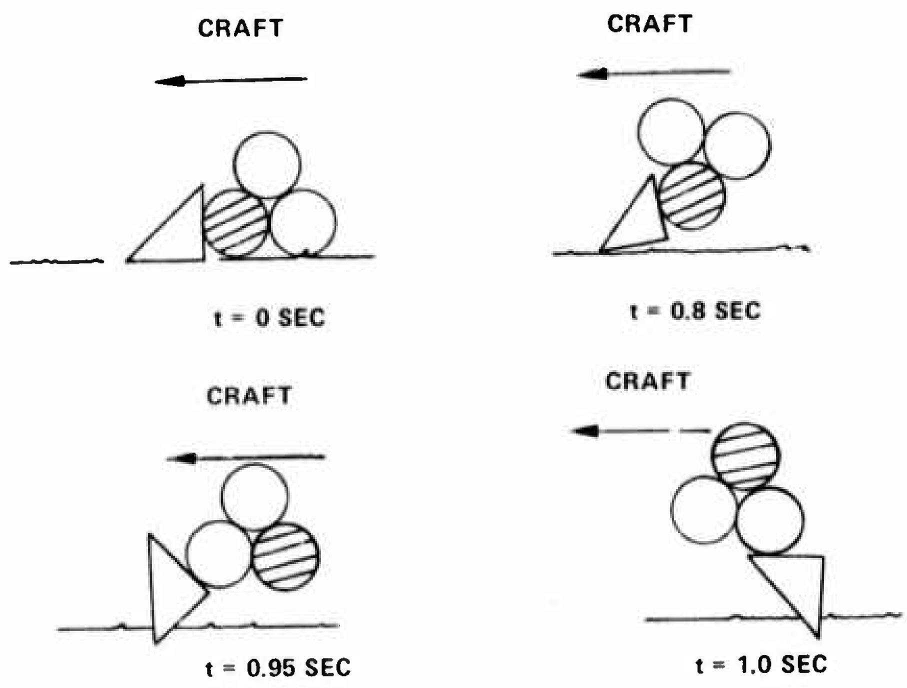


Figure 26 – Wooden Obstacle Damaged by Craft at Alameda NAS



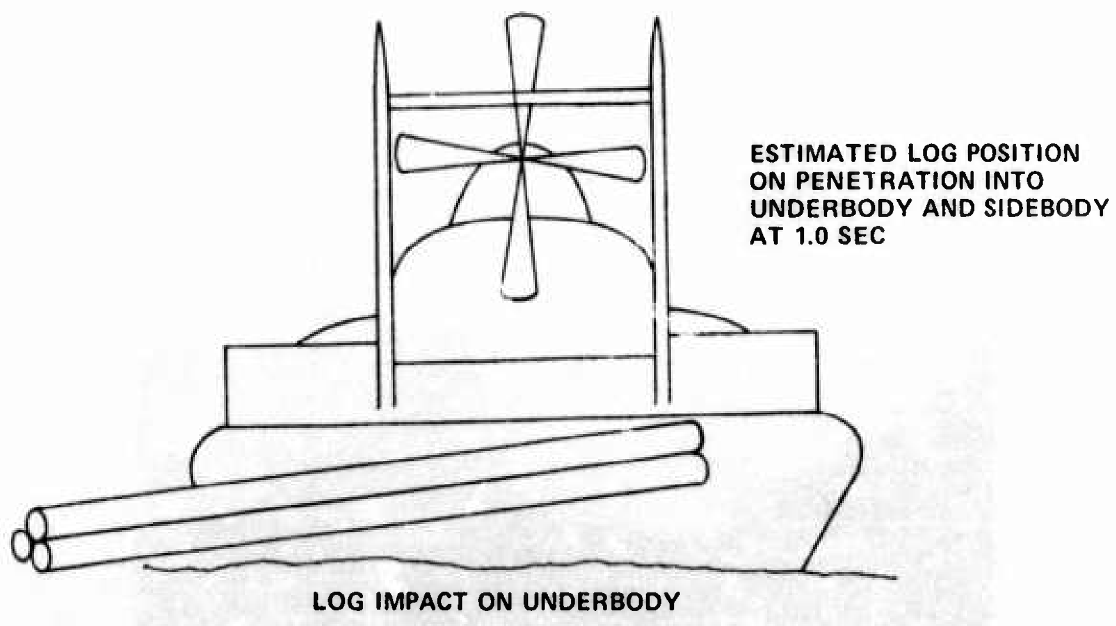


Figure 27 – Time Sequence as Craft Crossed Banded Piles and Resultant Impact

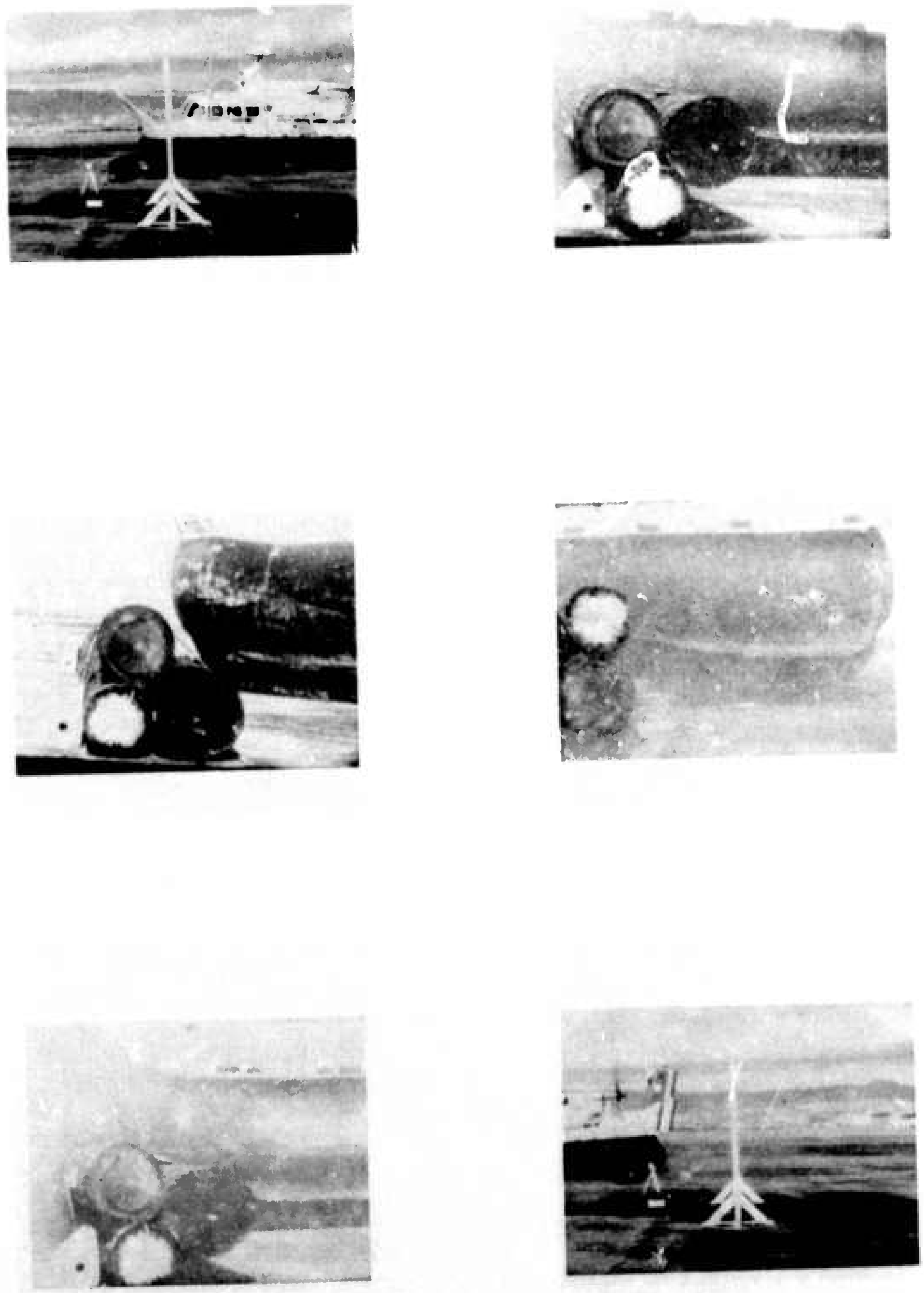
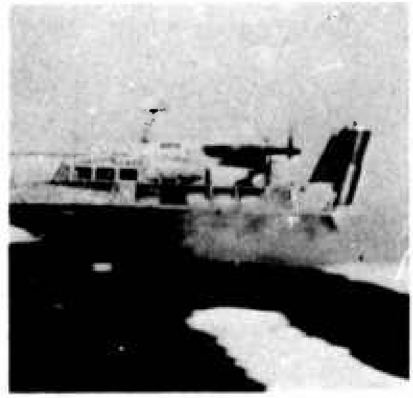


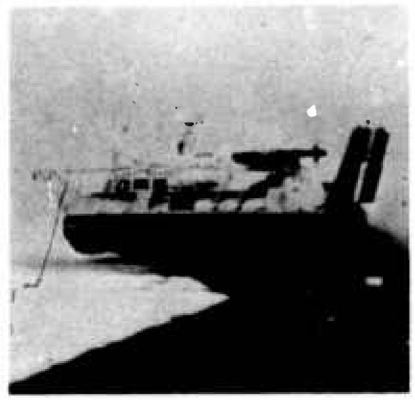
Figure 28 – Pictorial Sequence as Craft Crossed Banded Piles

t = 0 SEC



t = 0.25 SEC

t = 0.50 SEC



t = 0.75 SEC

t = 1.00 SEC

t = 1.25 SEC

Figure 29 – Pictorial Sequence as Test Craft Crossed Natural Obstacle

Figure 30 – Peak Impact near Center of Gravity Accelerations versus Craft Velocity

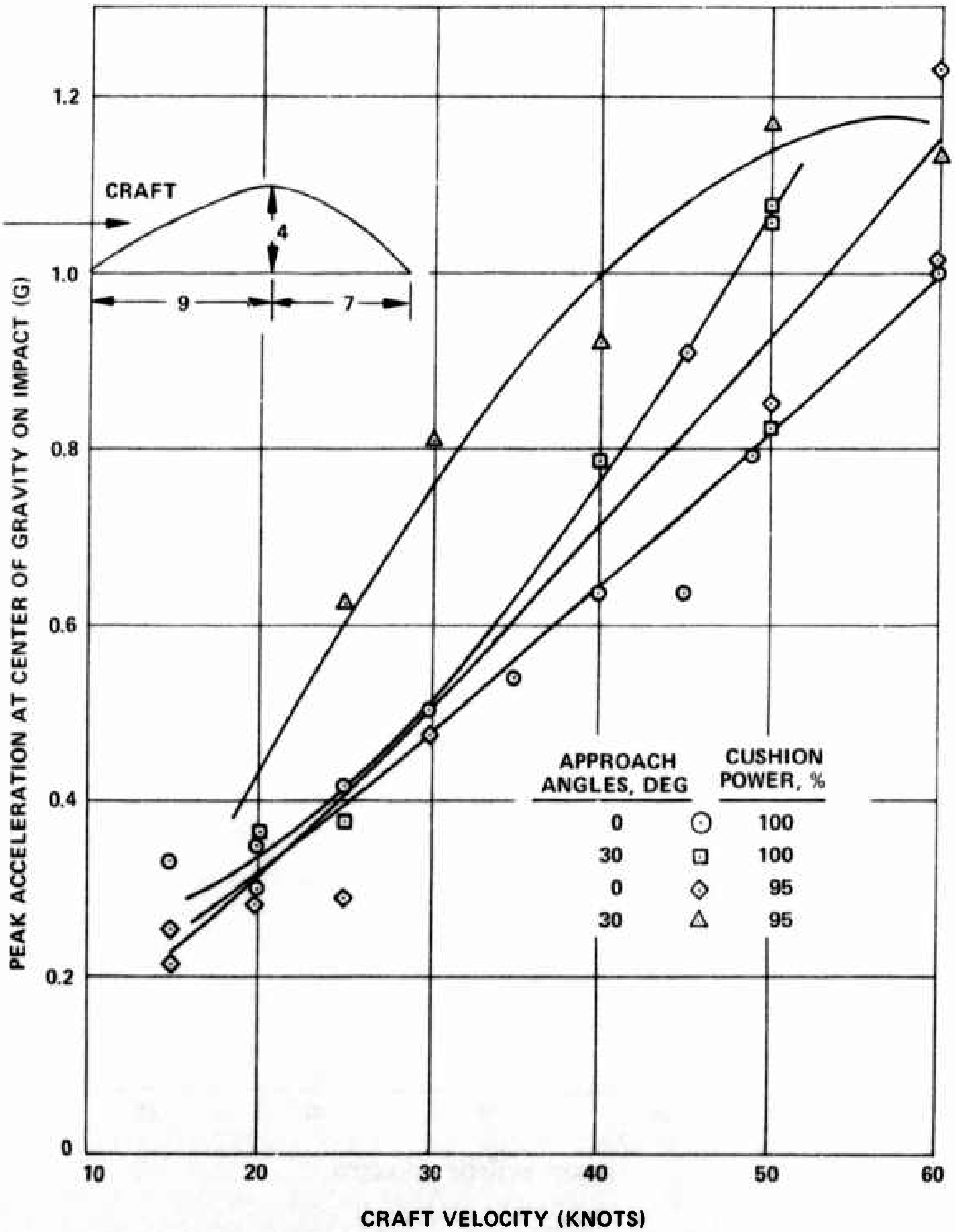


Figure 30a – Crossing of a 4-Foot Gravel Hill at Various Approach Angles and Cushion Power Settings

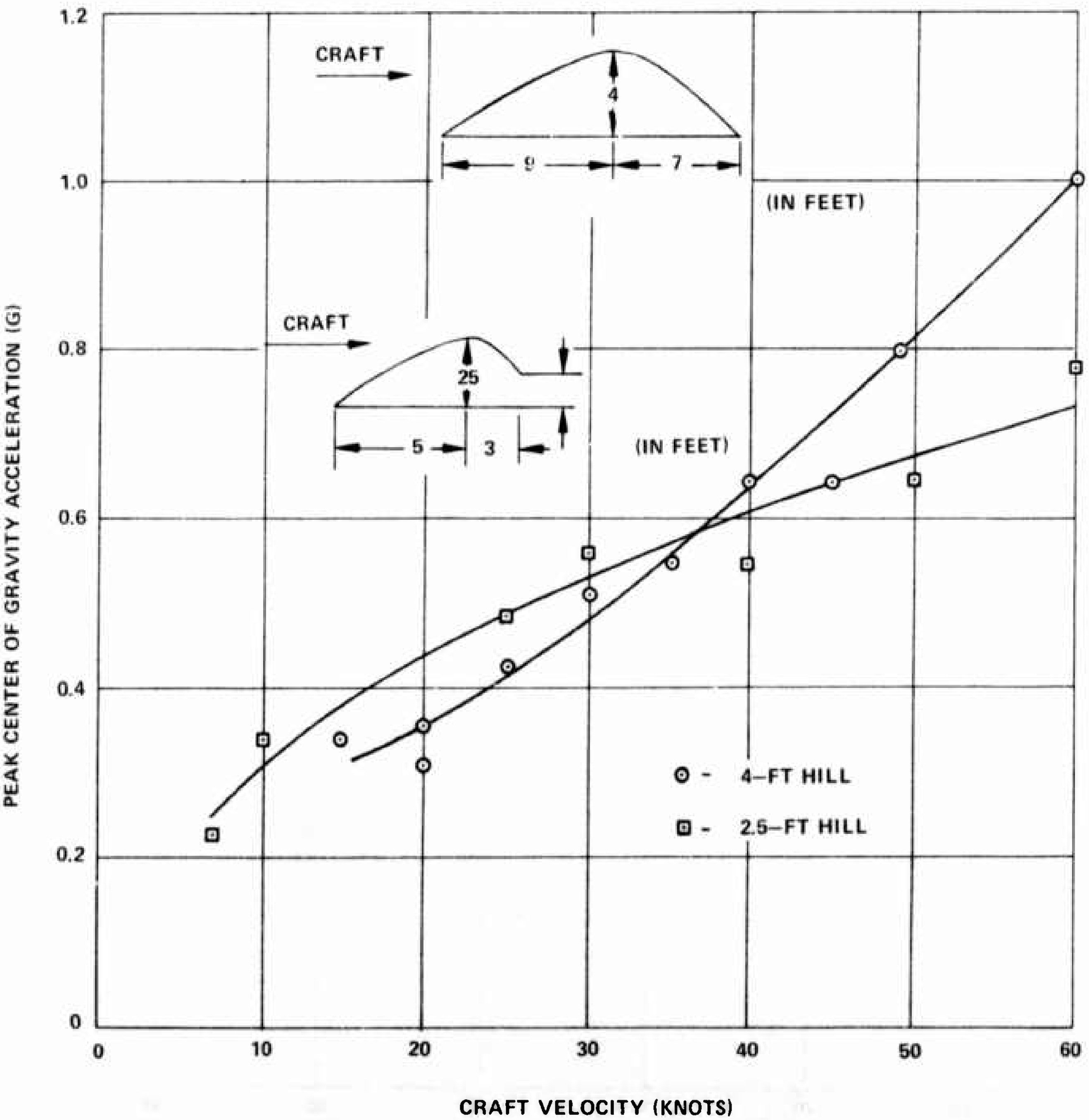


Figure 30b – Crossing 2.5- and 4-Foot Gravel Hills at 0-Degree Approach Angle and 100-Percent Cushion Power

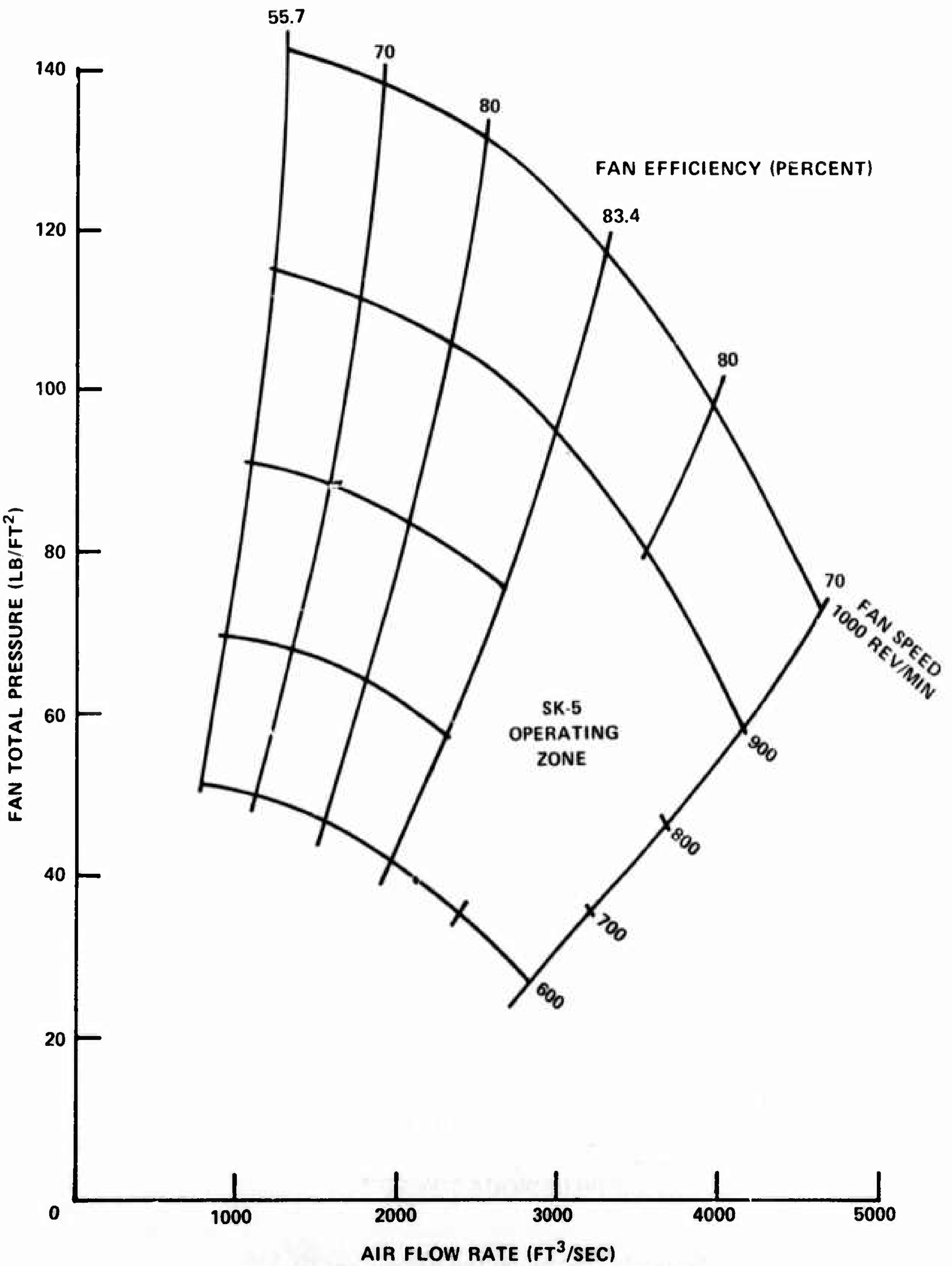


Figure 31 – Characteristics of Test Craft Lift Fan

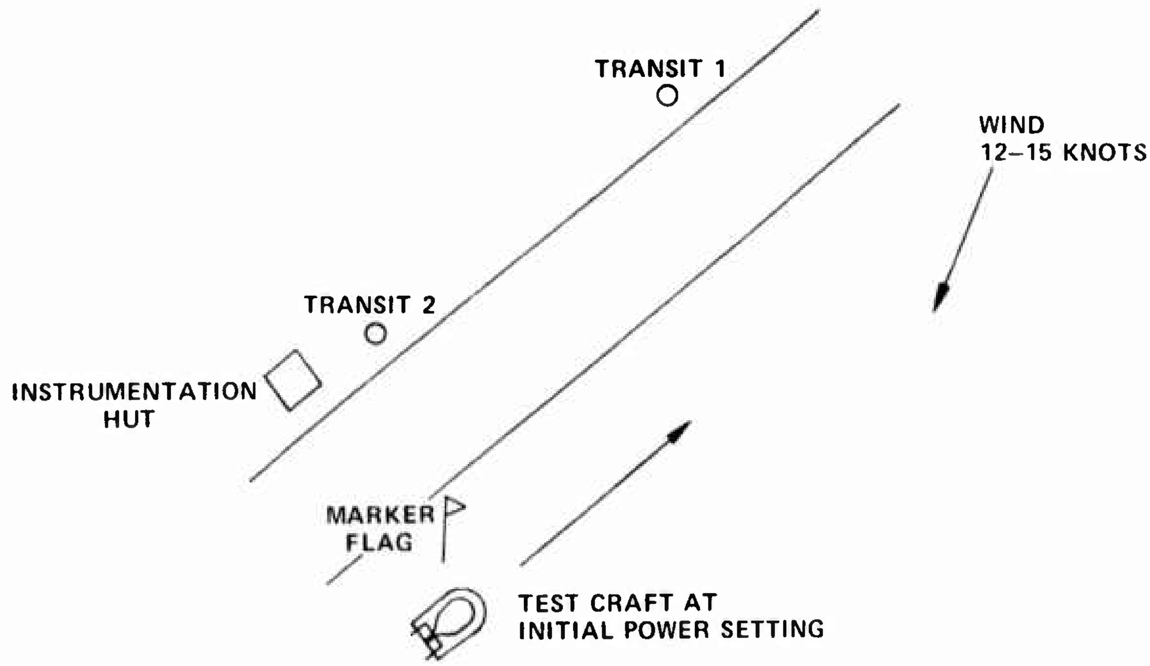


Figure 32 – Test Site for Turning Tests over Snow

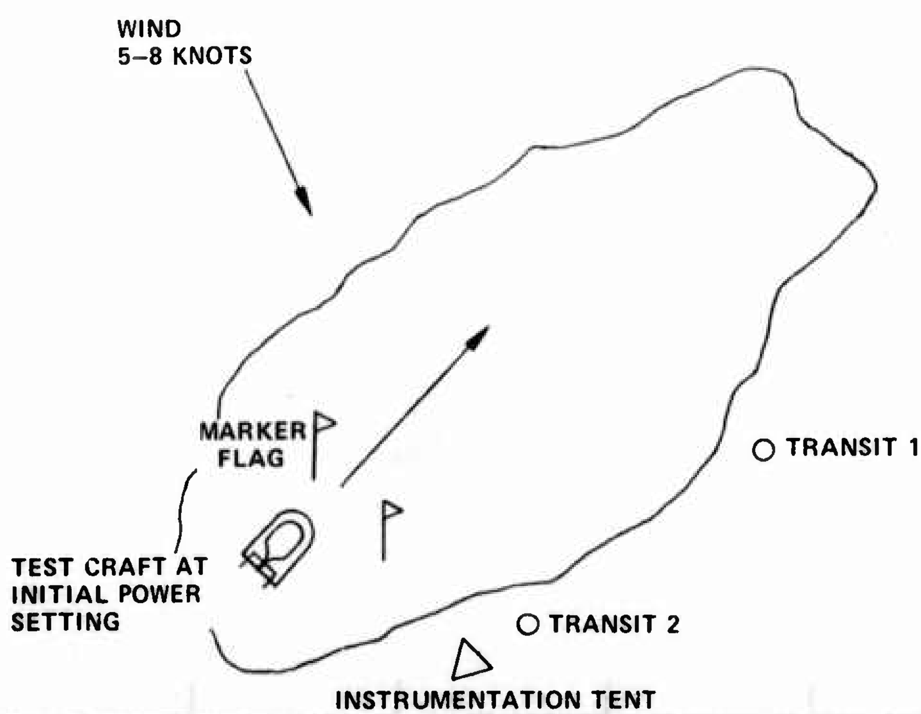


Figure 33 – Test Site for Turning Tests over Tundra

RUN NUMBER	INITIAL VELOCITY KNOTS	RUDDER ANGLE DEG	ELEVATOR ANGLE DEG	PROPELLER PITCH DEG	TURBINE SETTING PERCENT RPM	COMPRESSOR SETTING PERCENT RPM	PROPELLER THRUST LB	SKIRT JACKS	PUFF DATA	PORTS SHOULD BE
Δ60713A	19.4	30.0L	−8.6	+20	88.4	88.8	2340	PORT	SFPA	SFPA
+50714	23.7	30.0L	+9	+22	91.0	90.0	2340	FWD	SFPA	SFPA
x60715	20.5	30.0L	+9	+22	78.5	90.0	2340		NONE	NONE

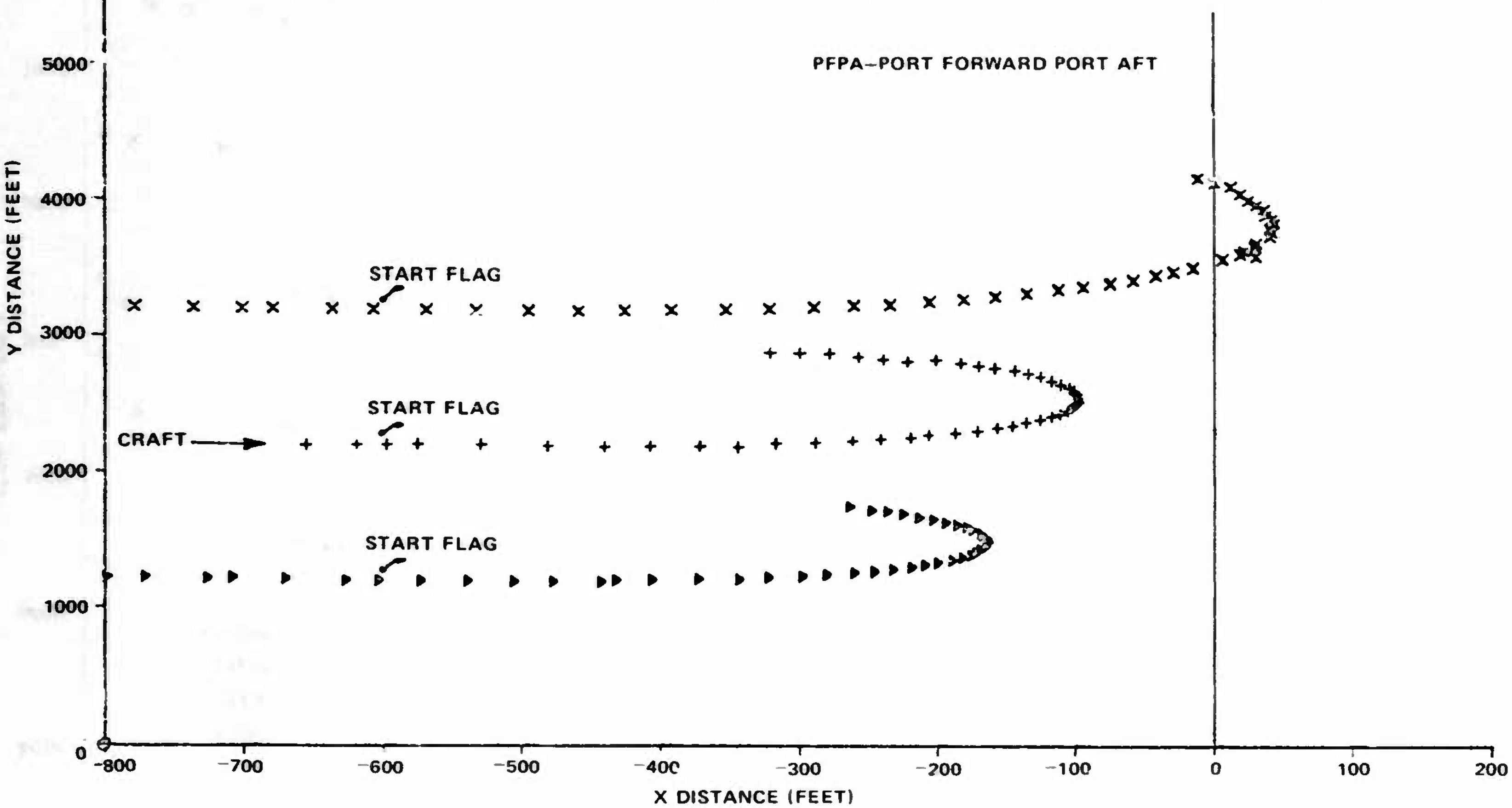
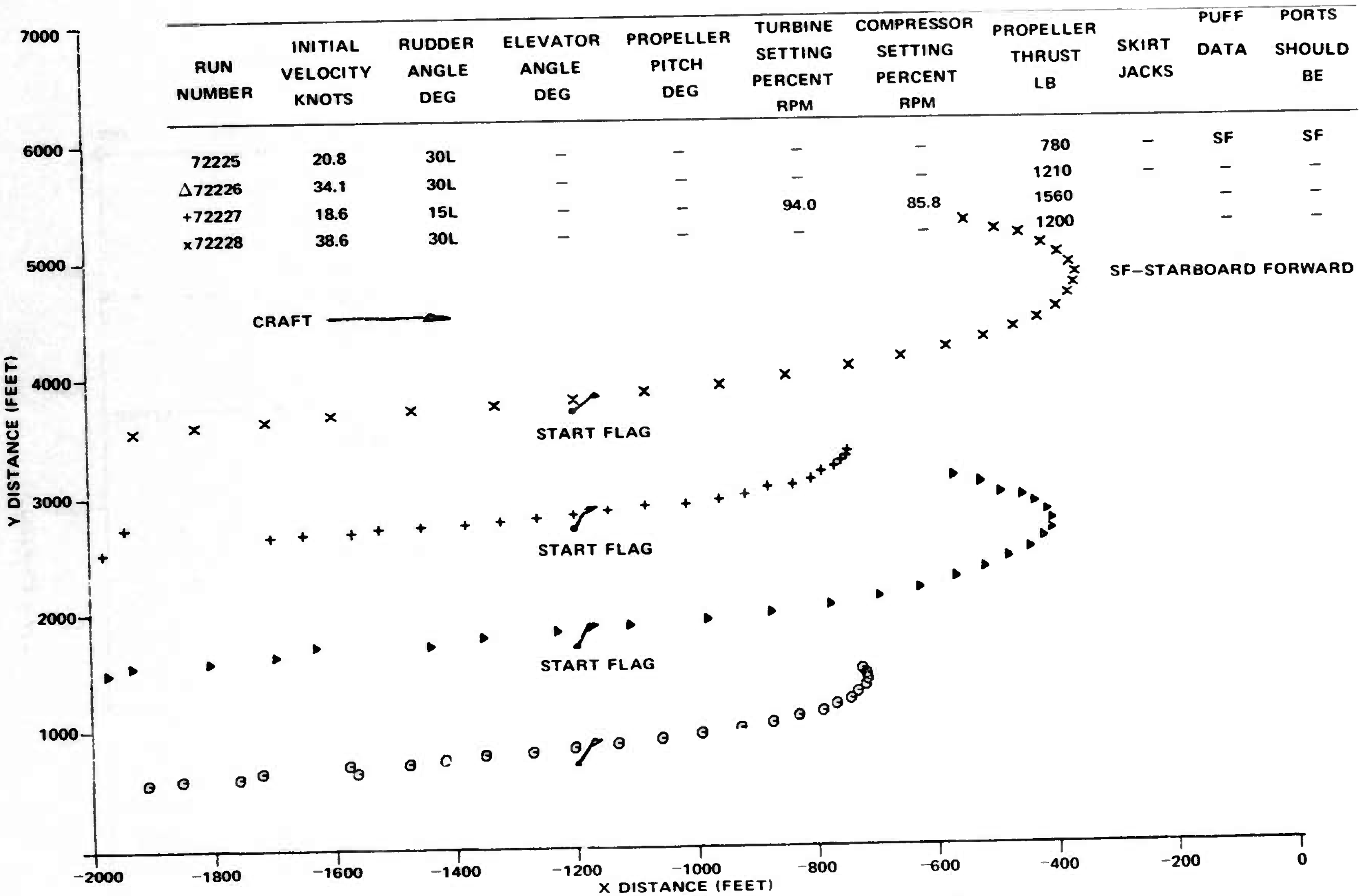


Figure 34 – Track of Craft during Turning Tests over Snow

(Time increment is 1 sec)



RUN NUMBER	INITIAL VELOCITY KNOTS	RUDDER ANGLE DEG	ELEVATOR ANGLE DEG	PROPELLER PITCH DEG	TURBINE SETTING PERCENT RPM	COMPRESSOR SETTING PERCENT RPM	PROPELLER THRUST LB	SKIRT JACKS	PUFF DATA	PORTS SHOULD BE
72225	20.8	30L	–	–	–	–	780	–	SF	SF
Δ72226	34.1	30L	–	–	–	–	1210	–	–	–
+72227	18.6	15L	–	–	94.0	85.8	1560		–	–
x72228	38.6	30L	–	–	–	–	1200		–	–

Figure 35 – Track of Craft during Turning Tests Over Tundra

(The time increment is 2 sec. The designation SF indicates starboard forward. Both puff port settings are given because of small differences between the indicated and the scheduled settings.)

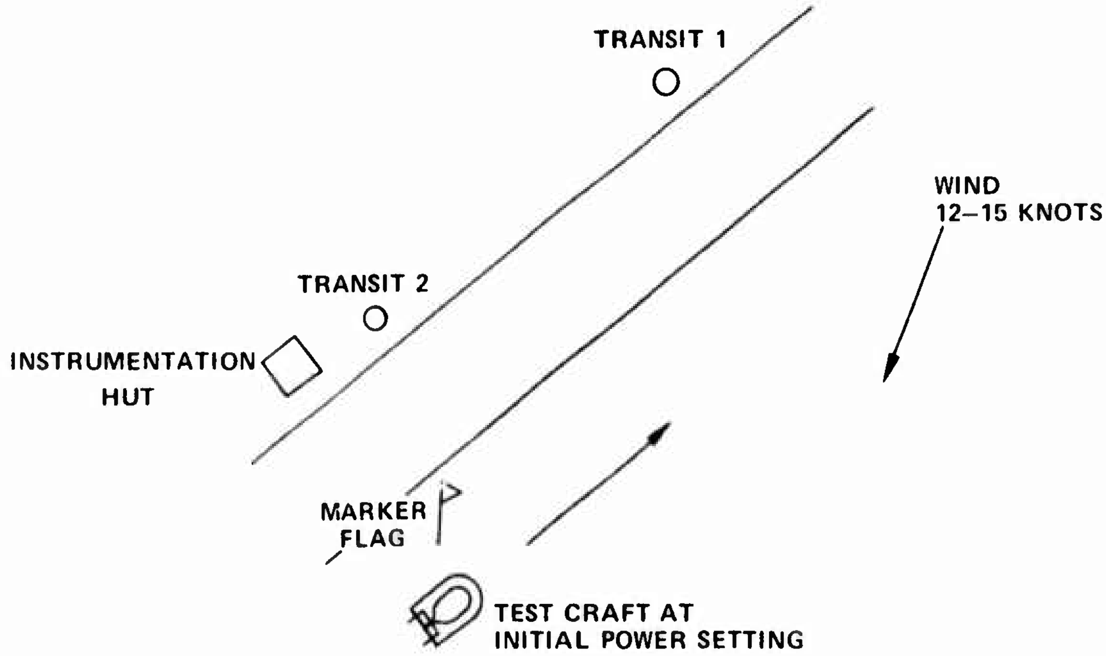


Figure 36 – Test Site for Deceleration Tests over Snow

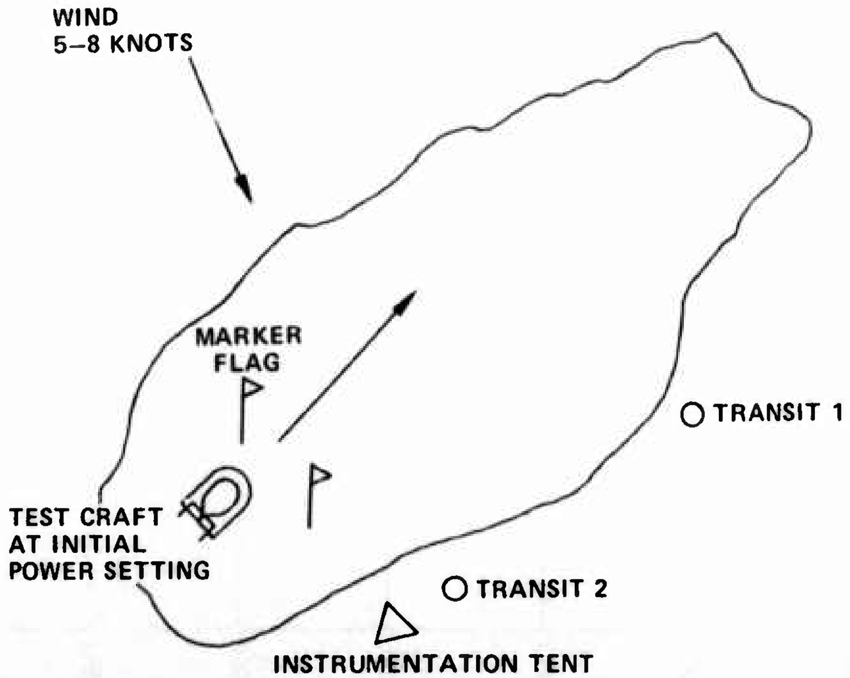


Figure 37 – Test Site for Deceleration Tests over Tundra

Figure 38 – Craft Track during Deceleration Tests over Snow

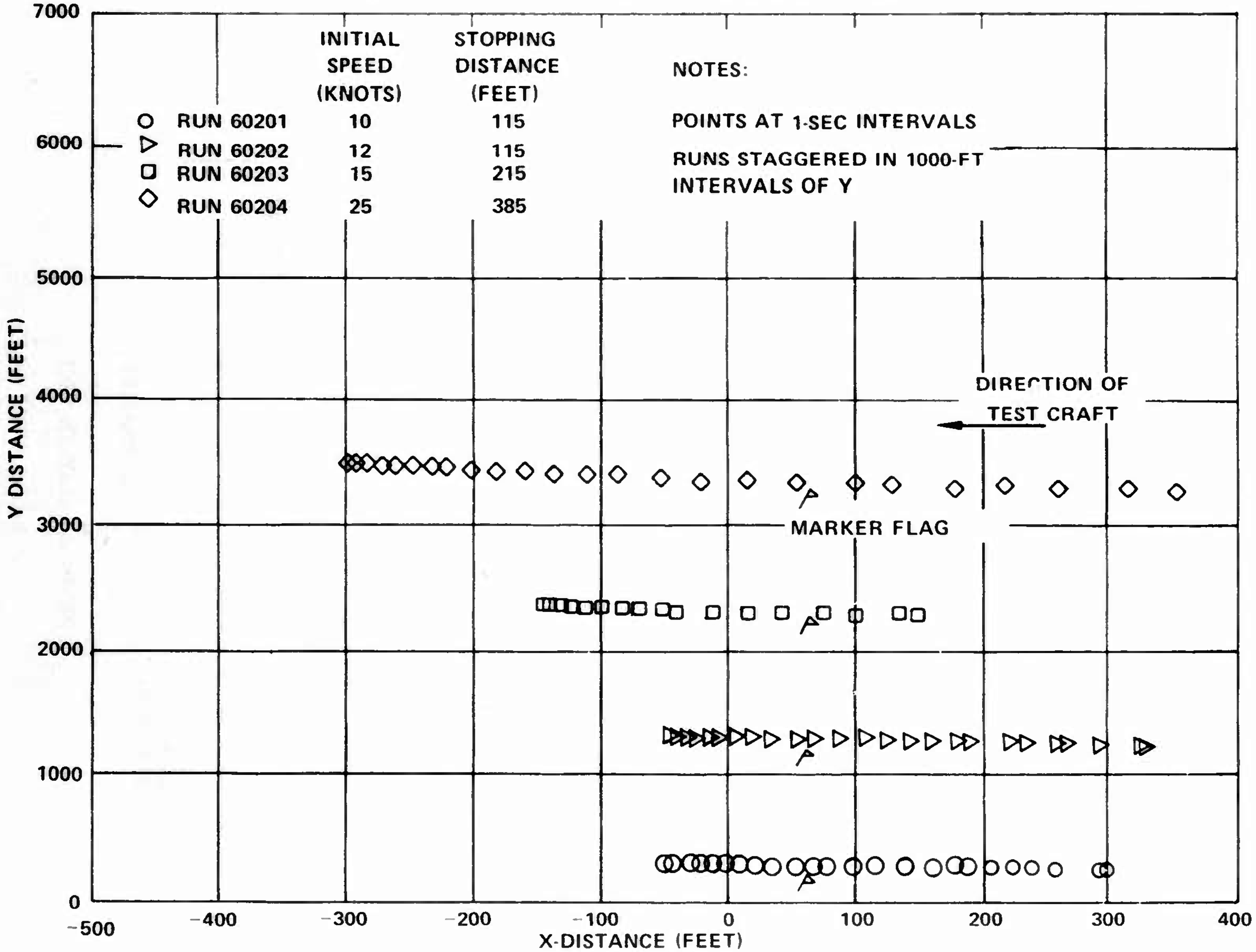


Figure 38a – Propeller Pitch Reversal (Method 1)

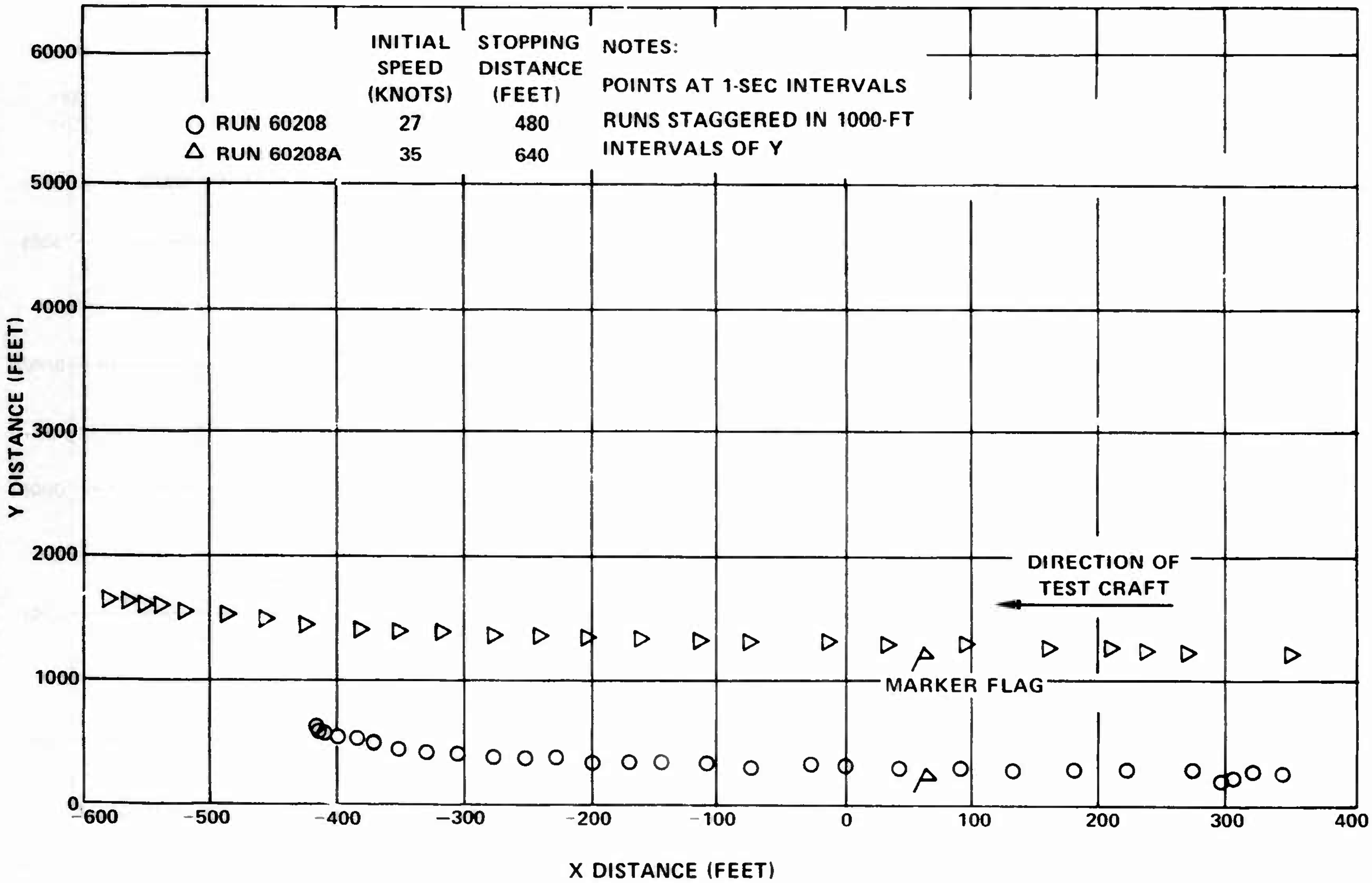


Figure 38b – Pirouette with Maximum Positive Propeller Pitch (Method 2)

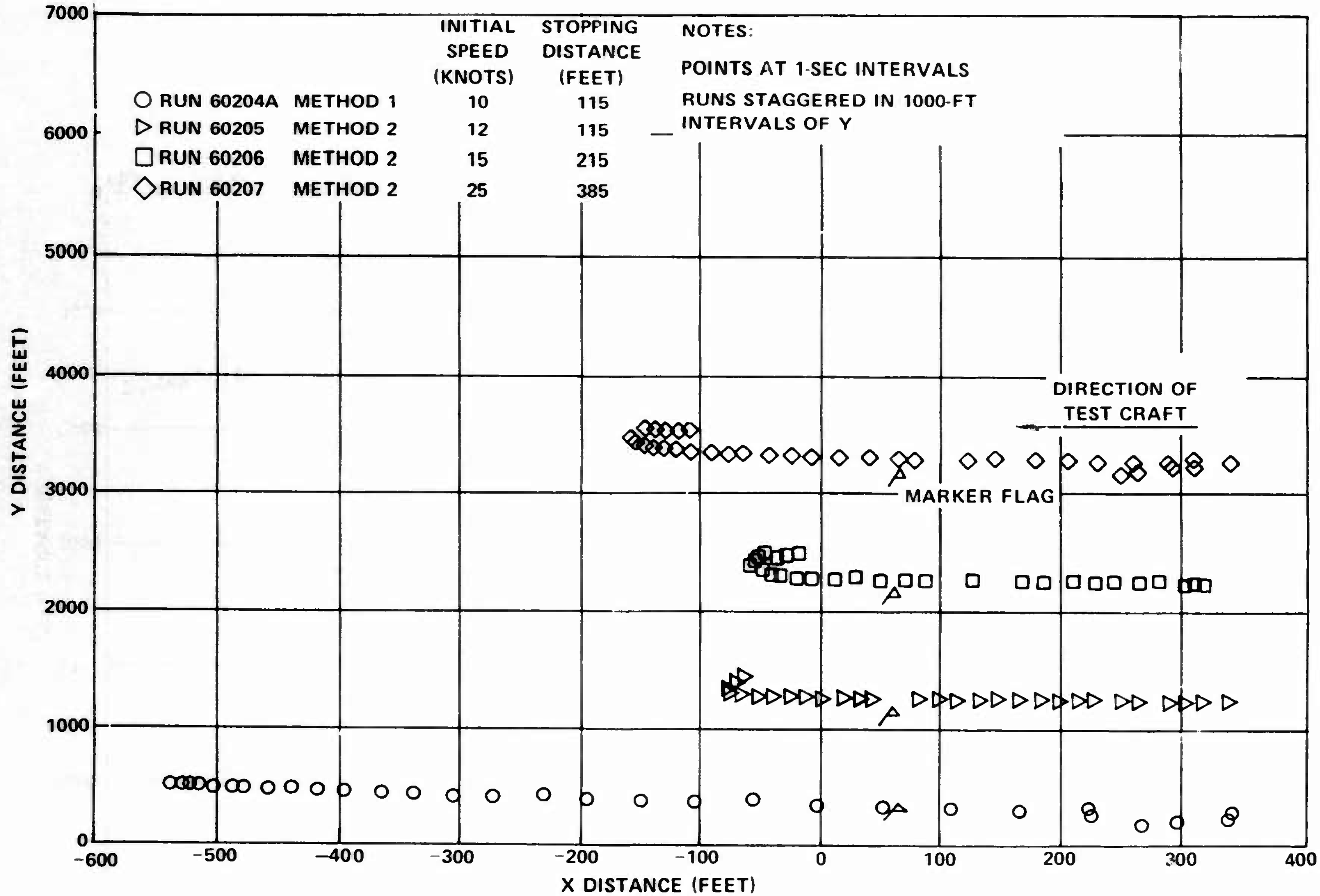


Figure 38c – Method 1 versus Method 2

Figure 39 – Craft Track during Deceleration Tests over Tundra

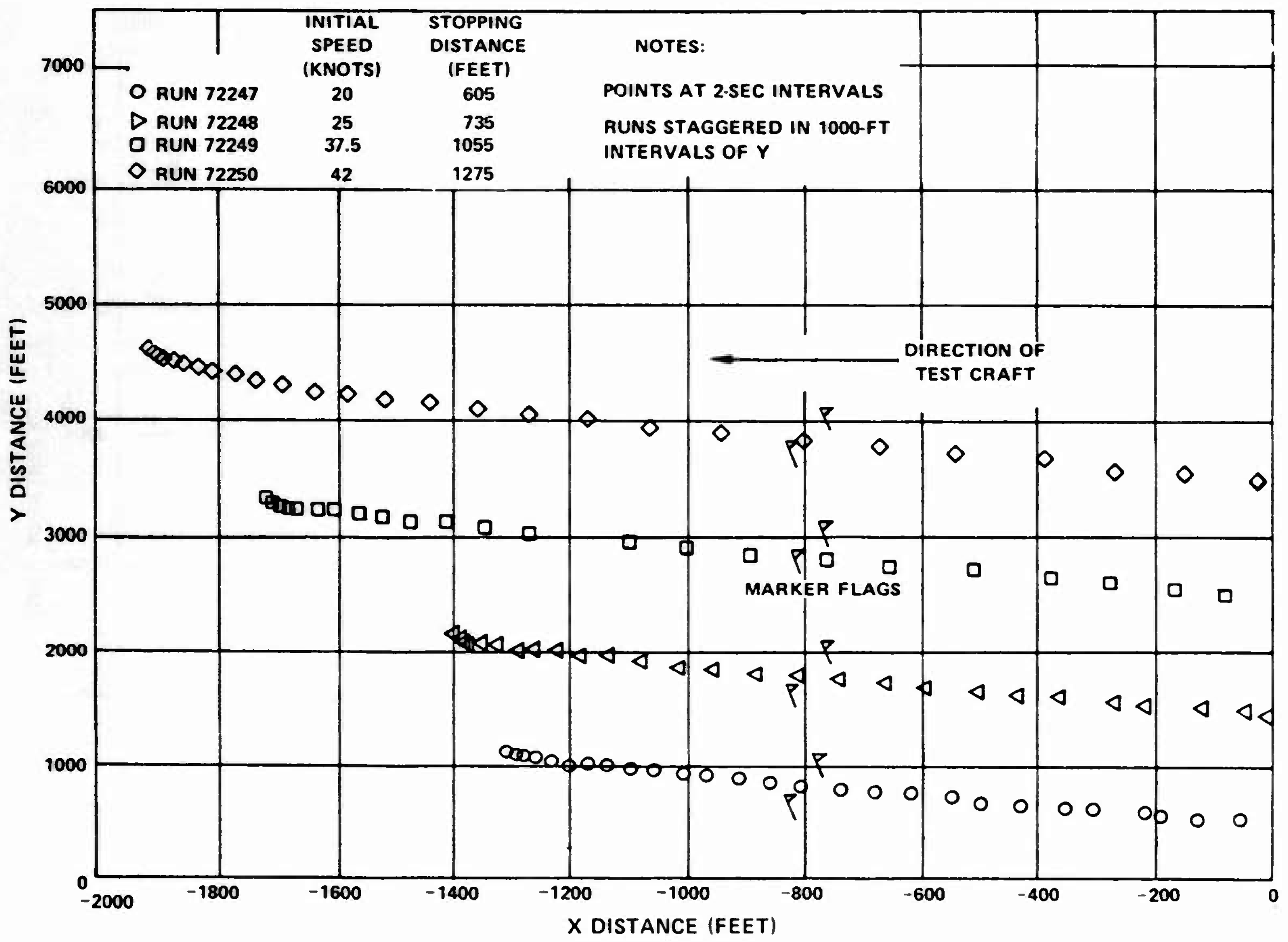


Figure 39a – Propeller Pitch Reversal (Method 1)

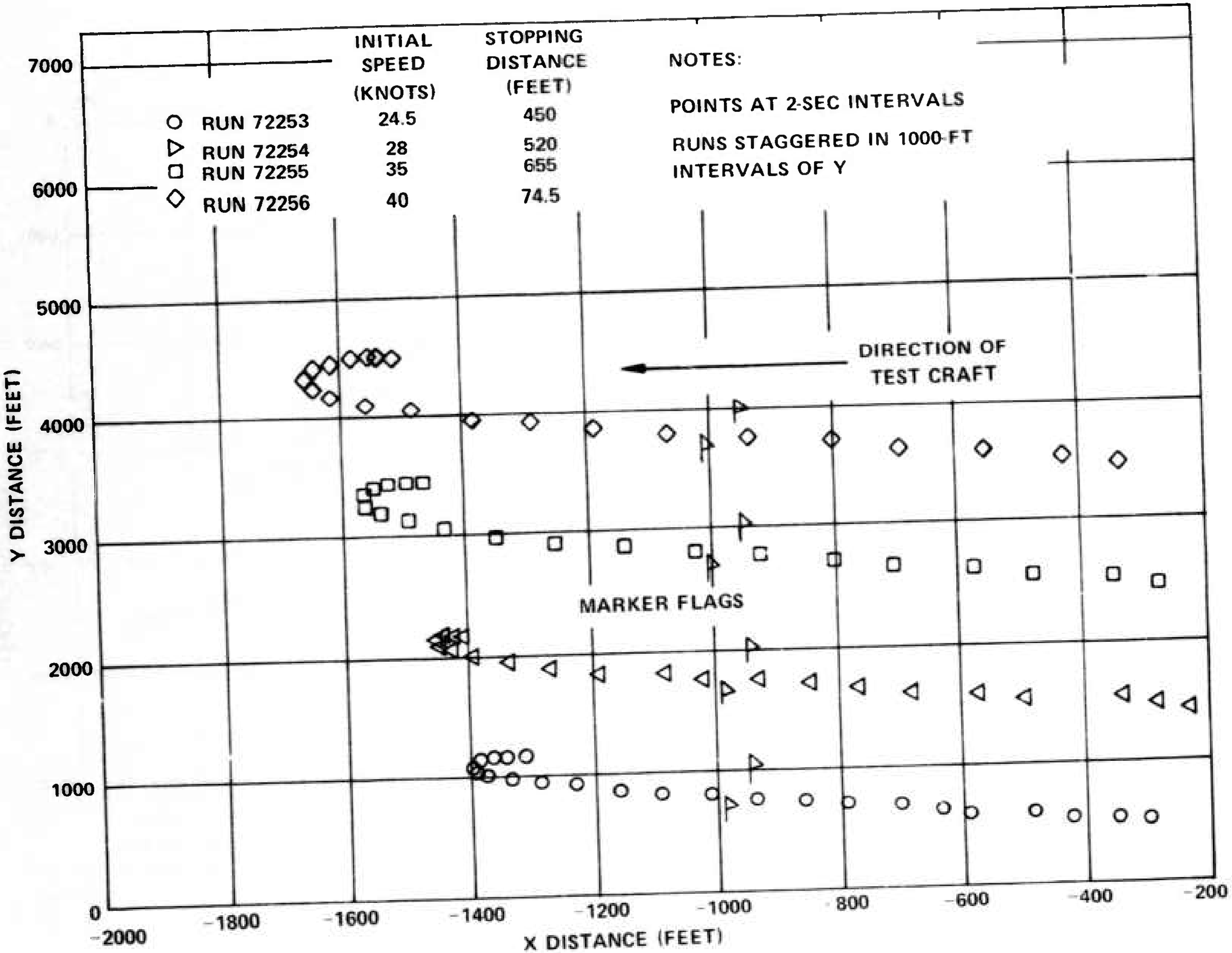
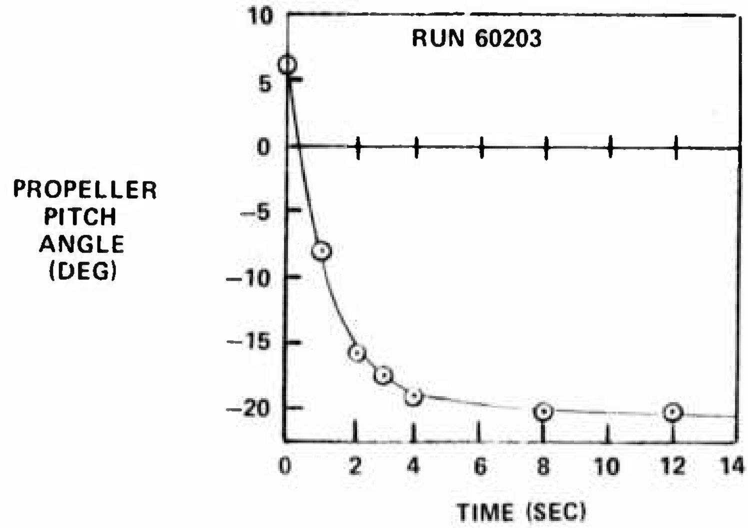


Figure 39b – Pirouette with Maximum Positve Propeller Pitch (Method 2)



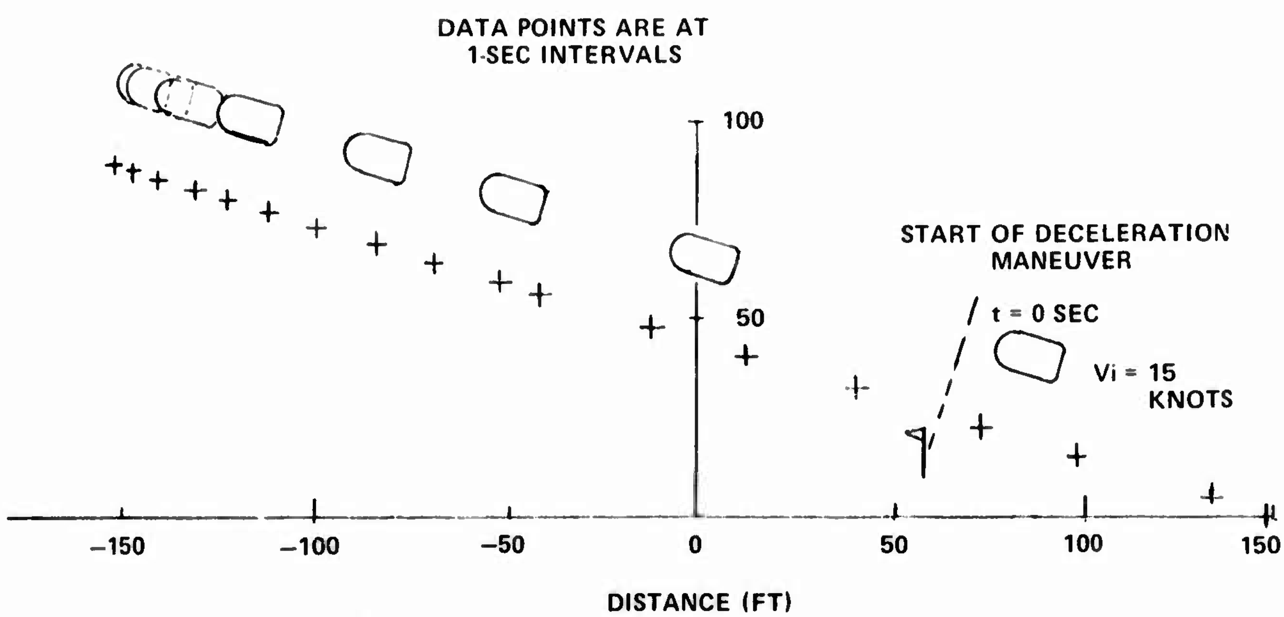


Figure 40 – Representative Time History of Propeller Pitch Angle during Deceleration by Method 1

(Stopping distance approximated to illustrate the reverse pitch maneuver)

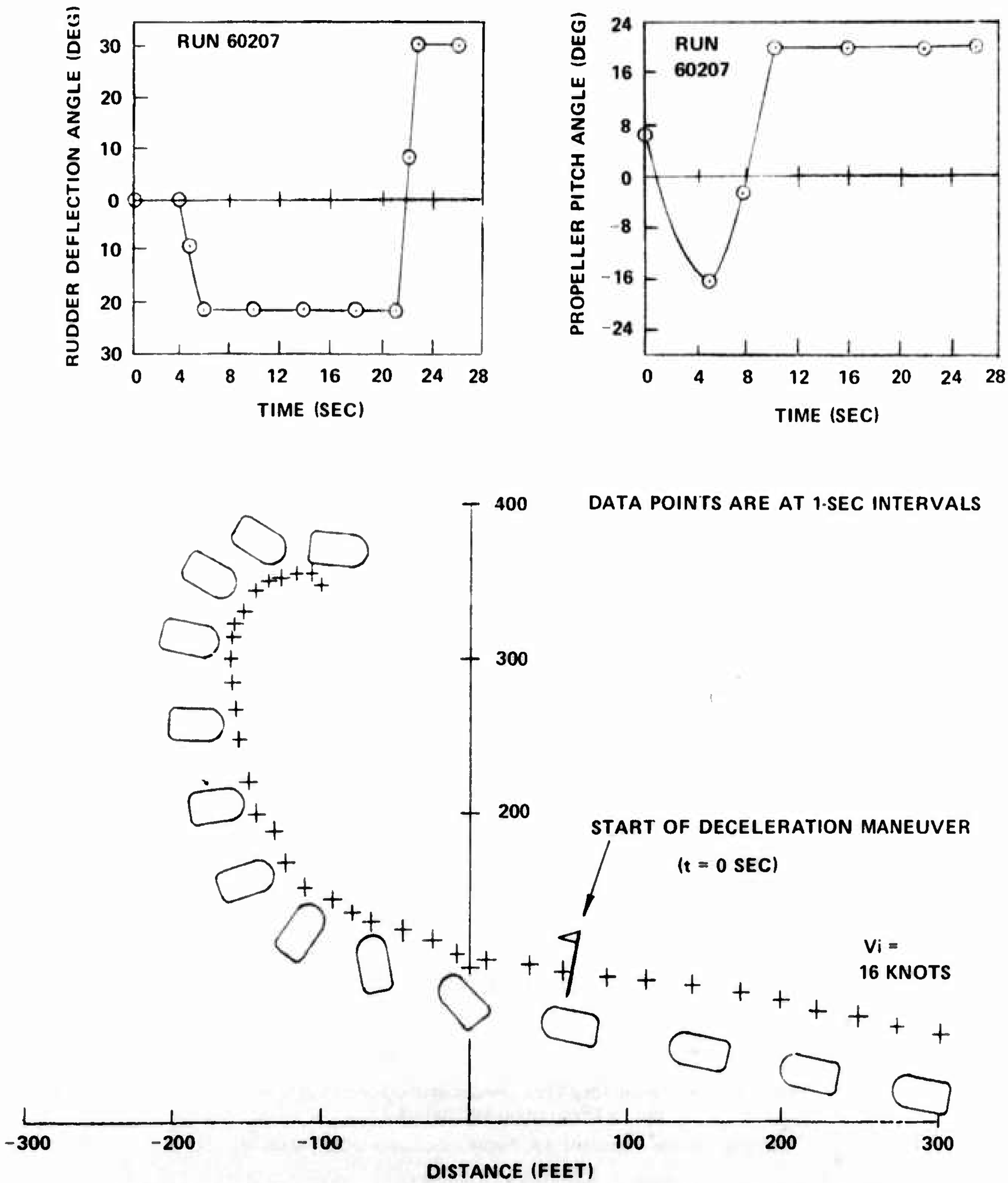


Figure 41 – Representative Time History of Rudder Deflection and Propeller Pitch Angle during Deceleration by Method 2

(Craft slip angle appropriated to illustrate the pirouette maneuver)

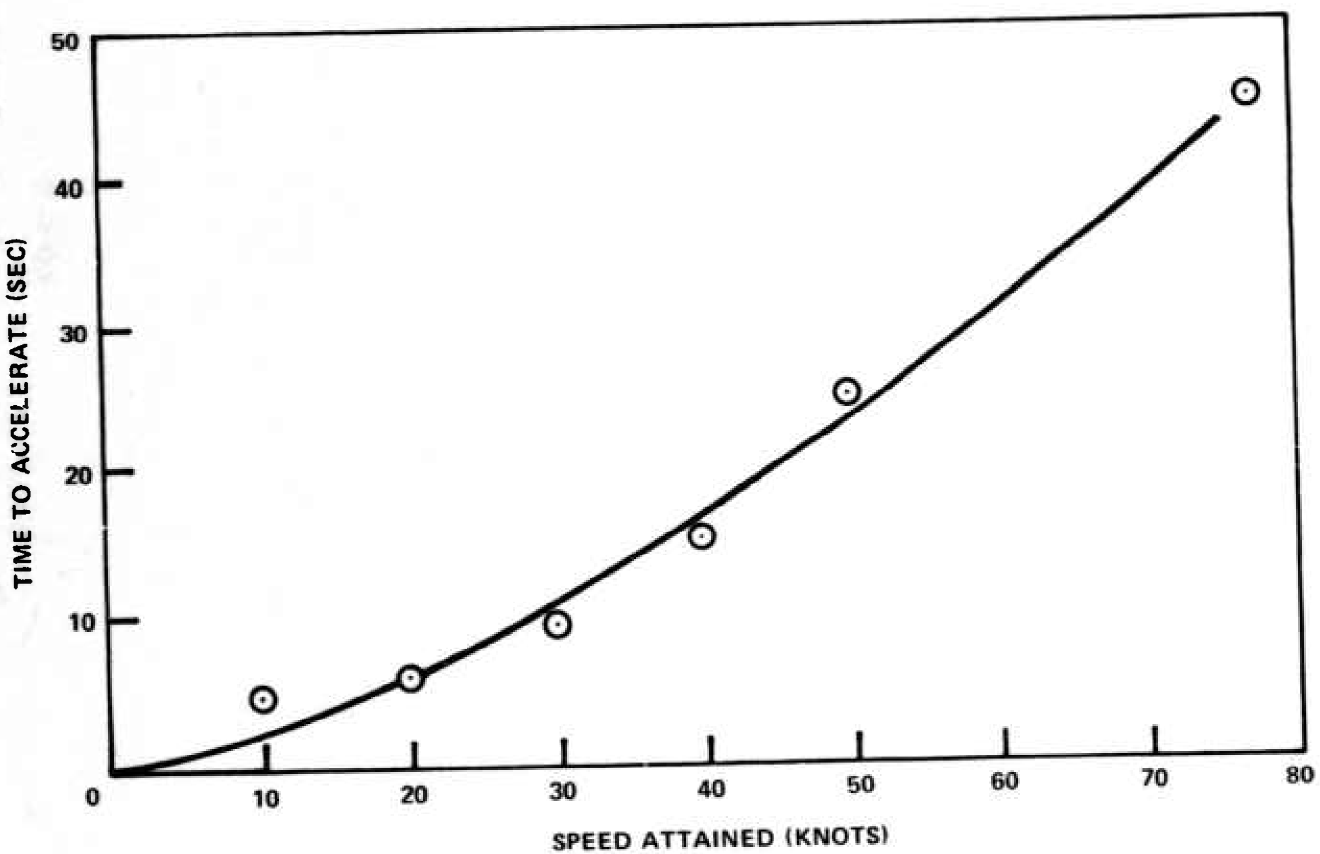


Figure 42 – Approximation of Acceleration Capability of the 10-Ton SEV at 97 Percent of Available Power

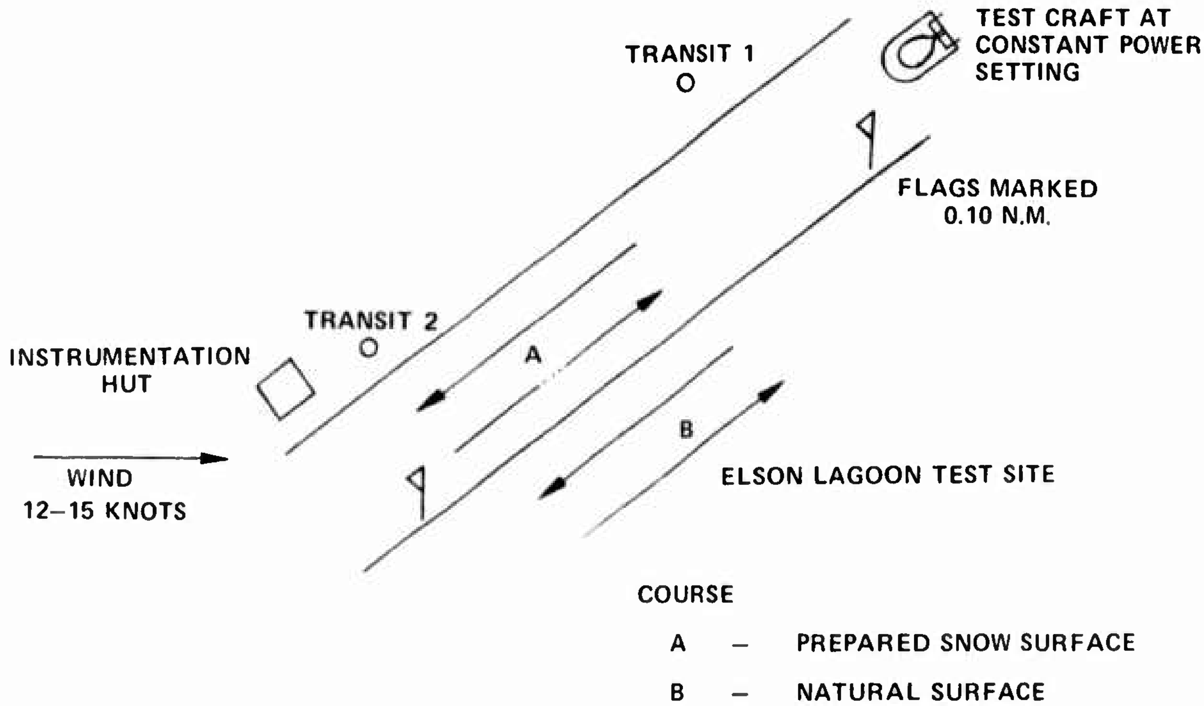


Figure 43 – Test Site for Skirt Drag Tests over Snow

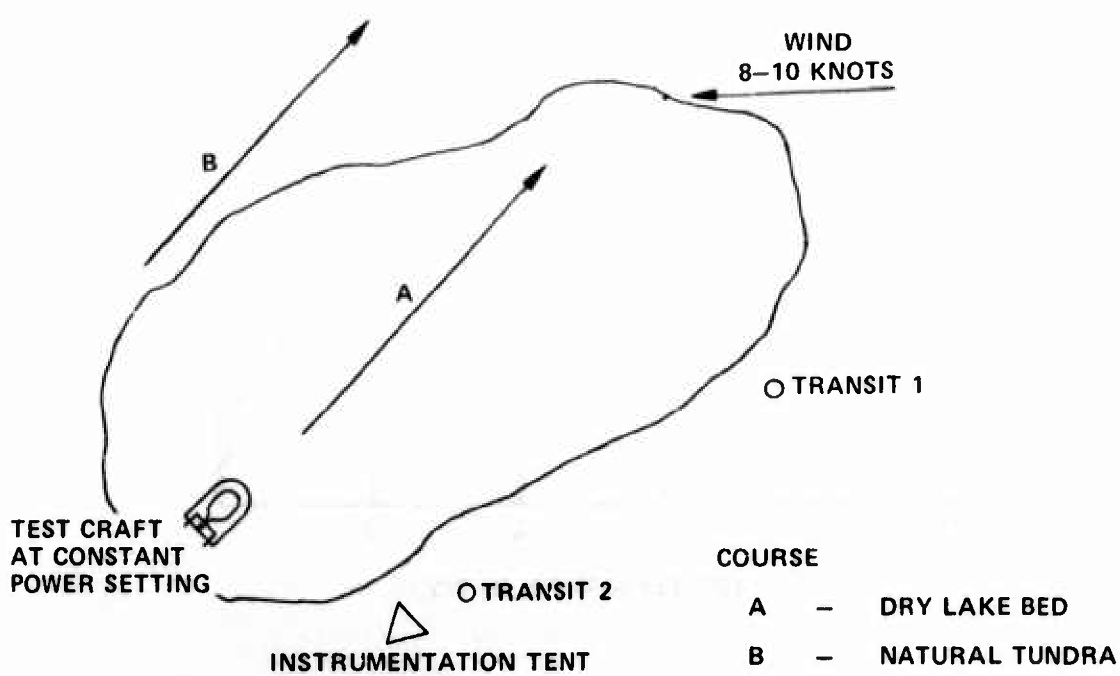


Figure 44 – Test Site for Skirt Drag Tests over Tundra

Figure 45 – Craft Trials during Skirt Drag Tests over Tundra

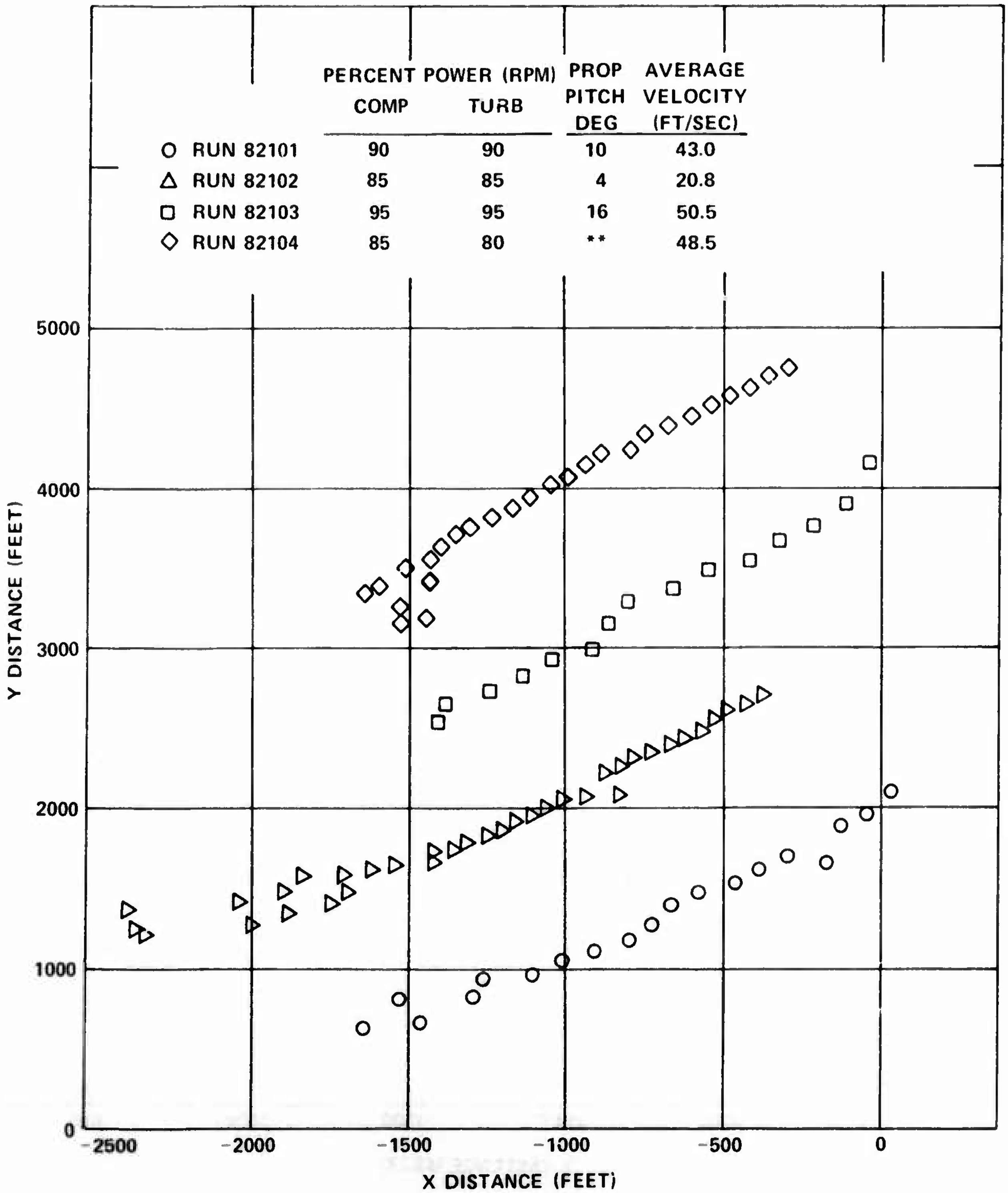


Figure 45a – Runs 82101–82104

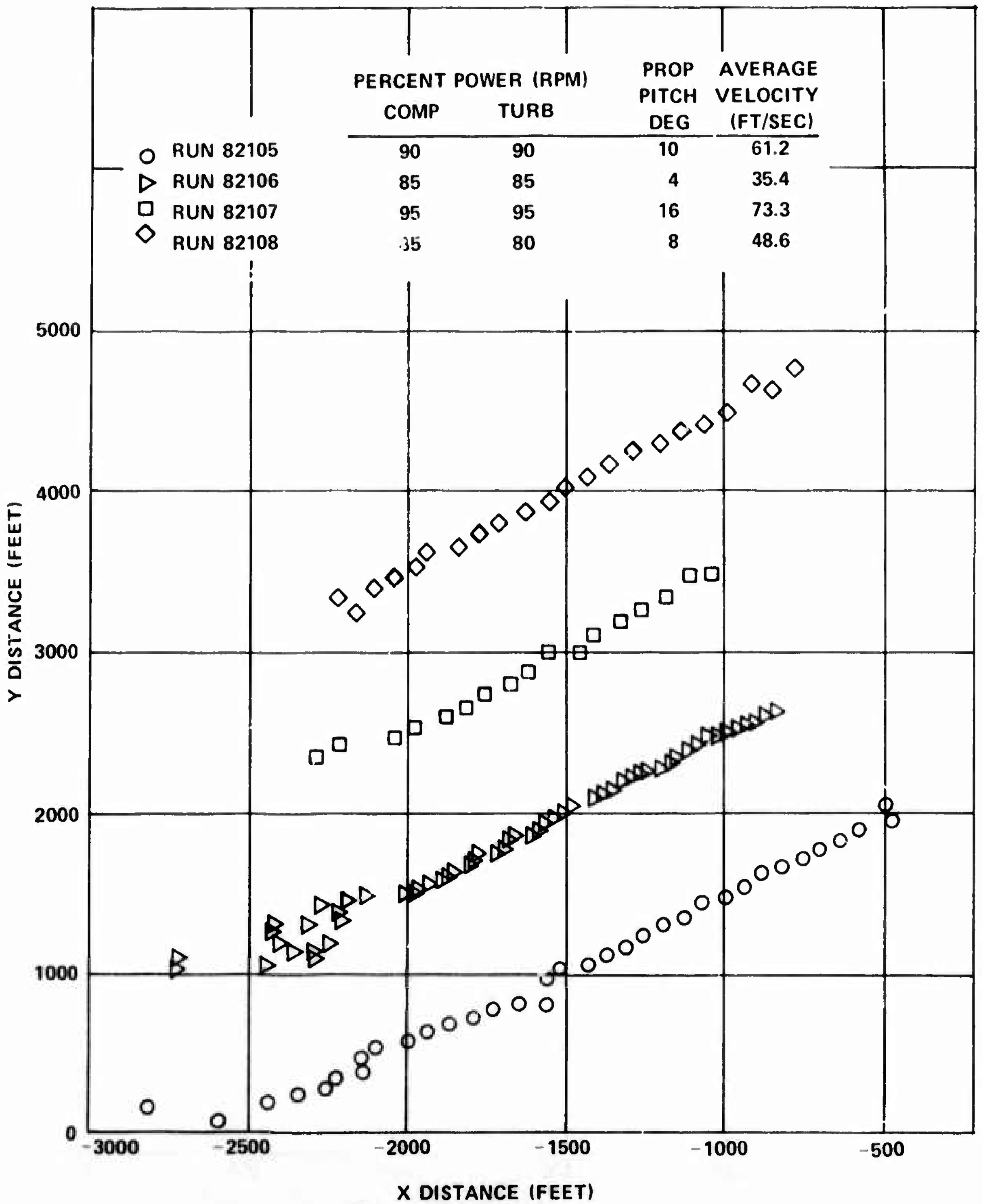


Figure 45b – Runs 82105–82108

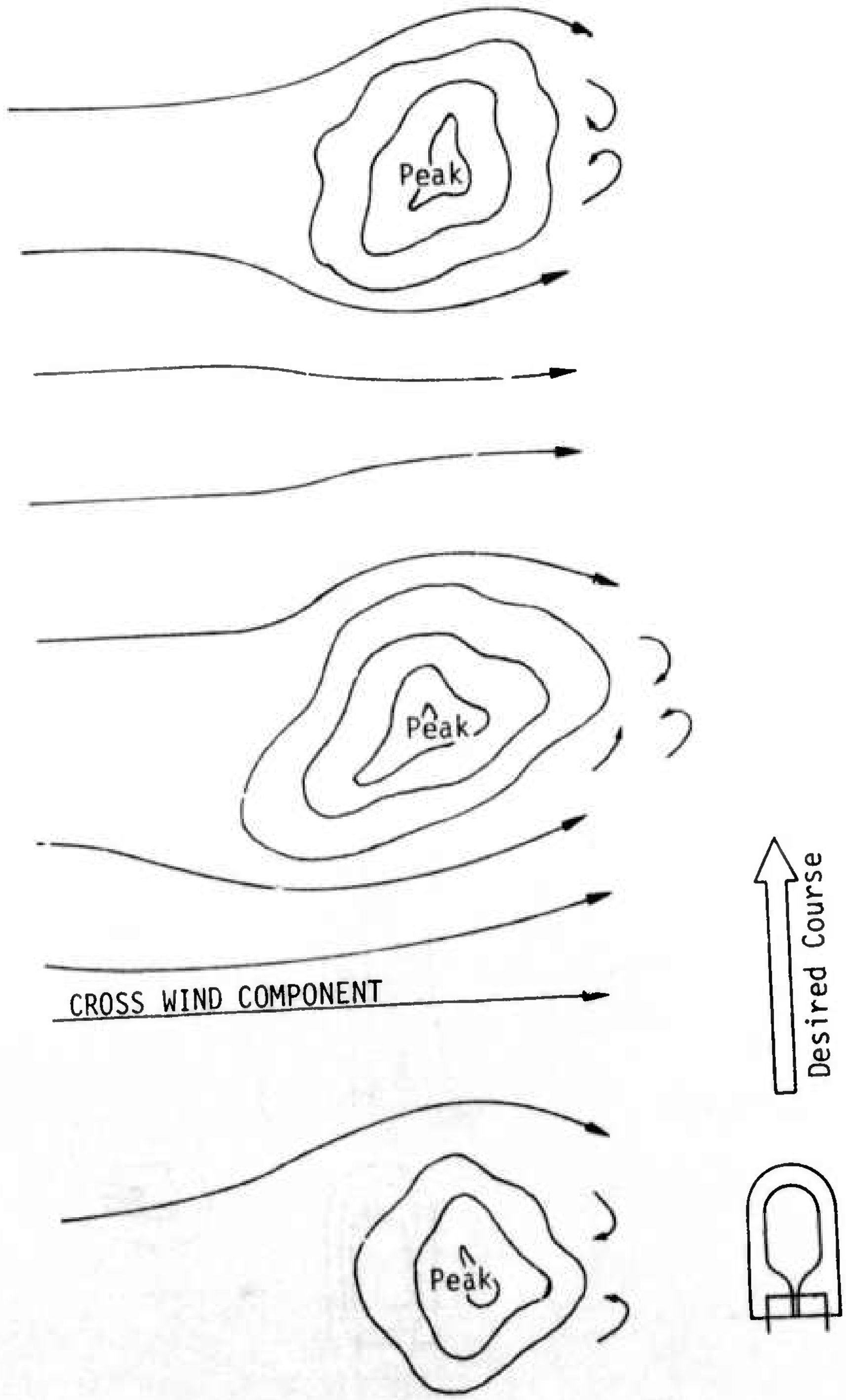


Figure 46 – Periodic Disturbance of Craft Course by Cross Winds
(Cross wind is alternately blocked and unblocked by a nearby line of ridges)

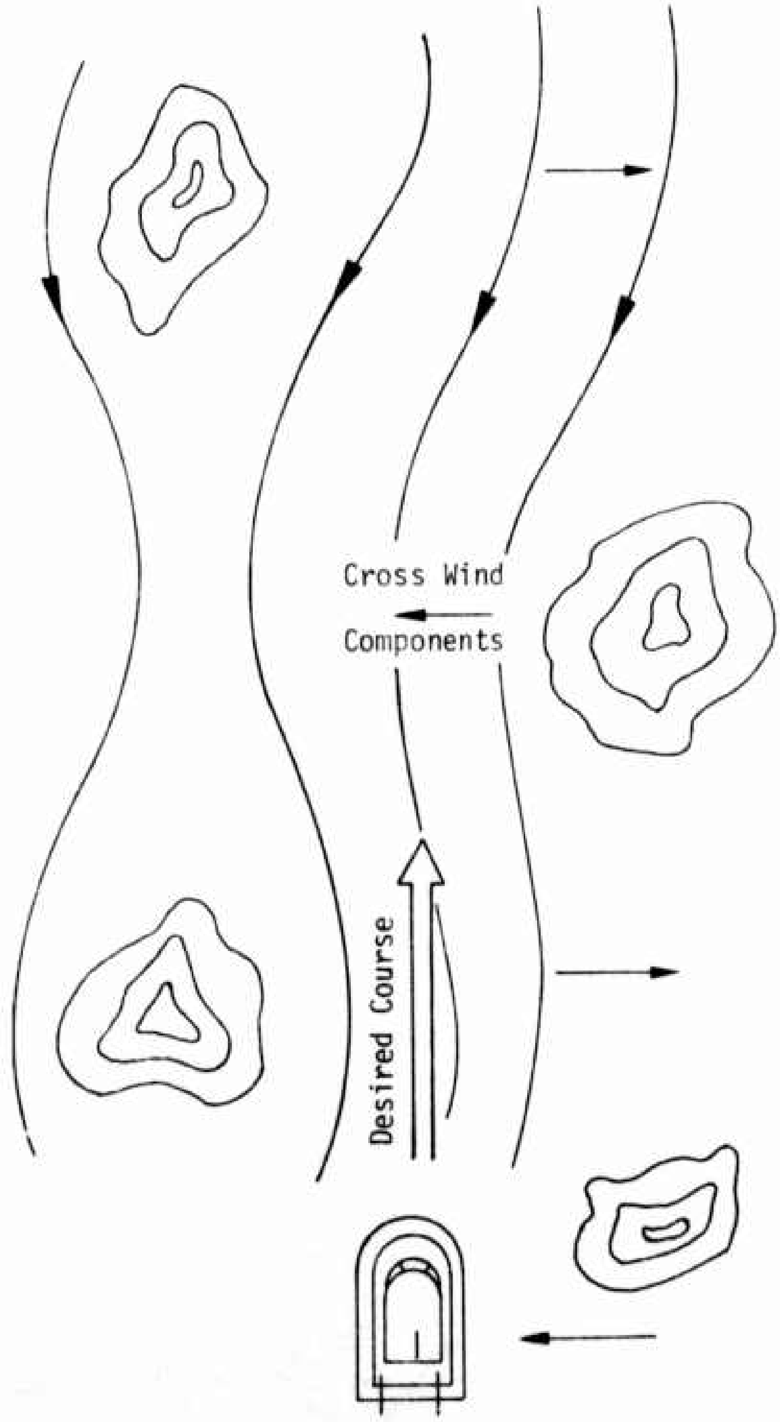


Figure 47 – Periodic Disturbance of Craft Course by Head Winds

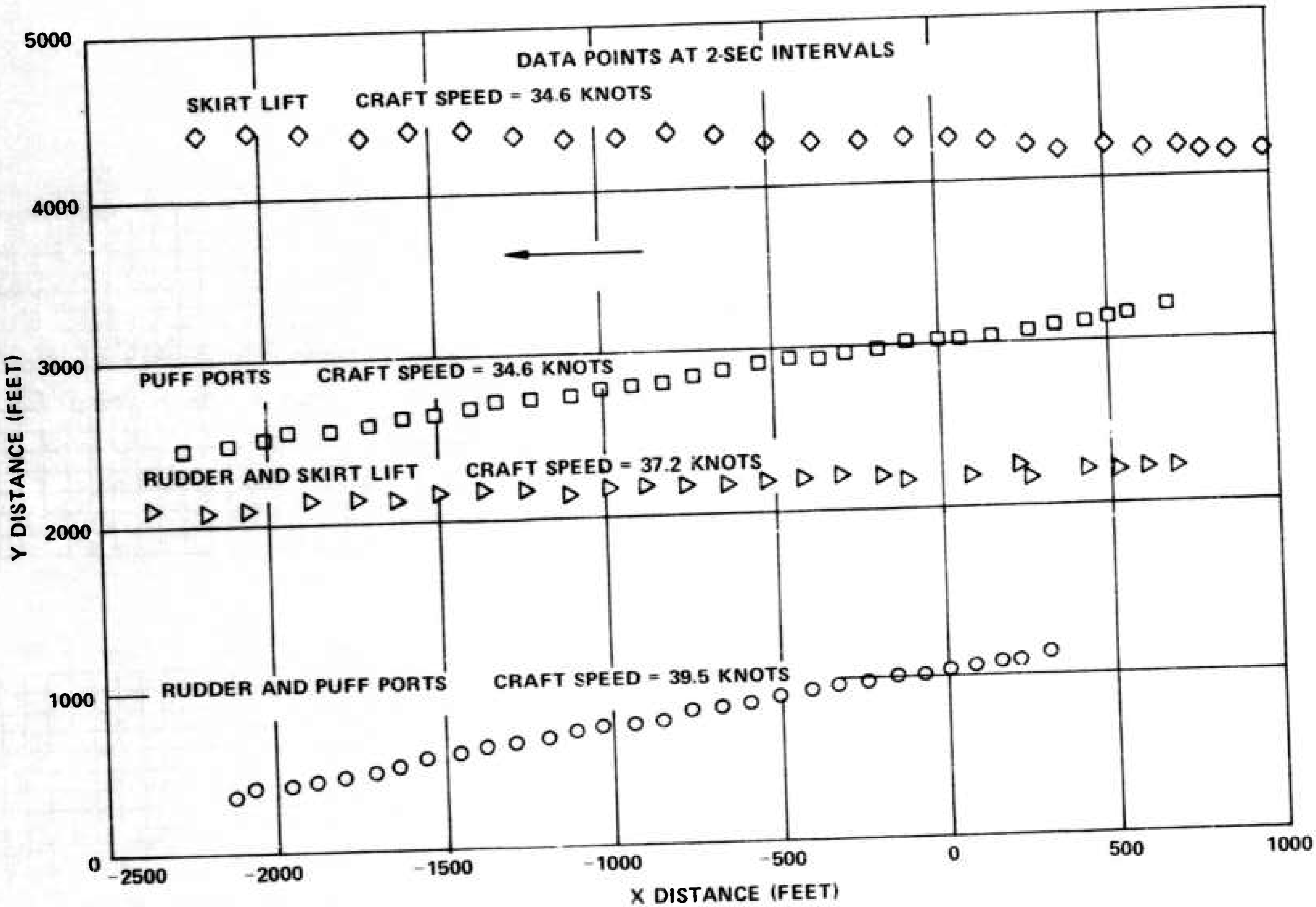


Figure 48 – Typical Craft Tracks du:ing Pilot-Induced Oscillation

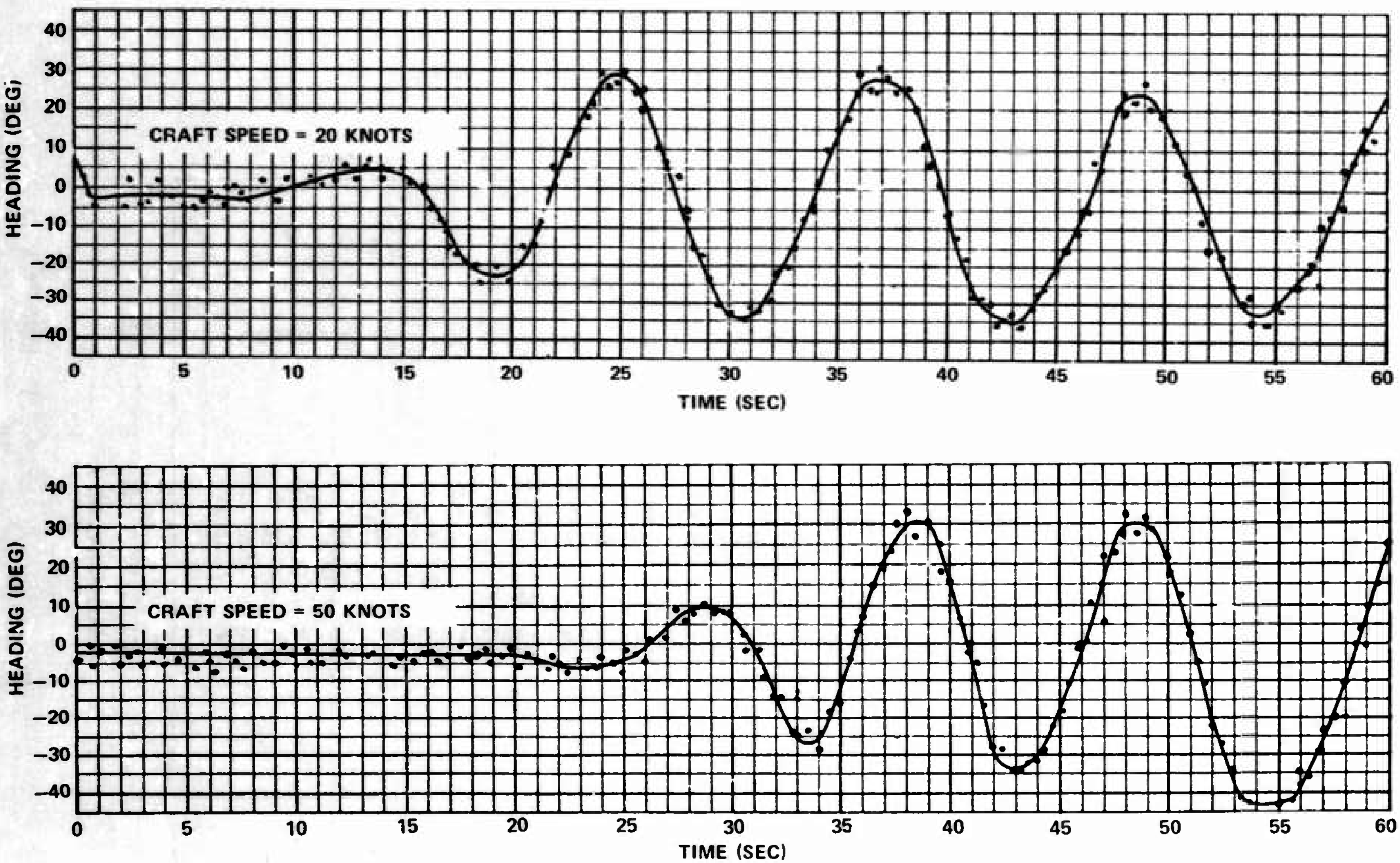


Figure 49 – Variation in Craft Heading with Time for Rudder Actuation

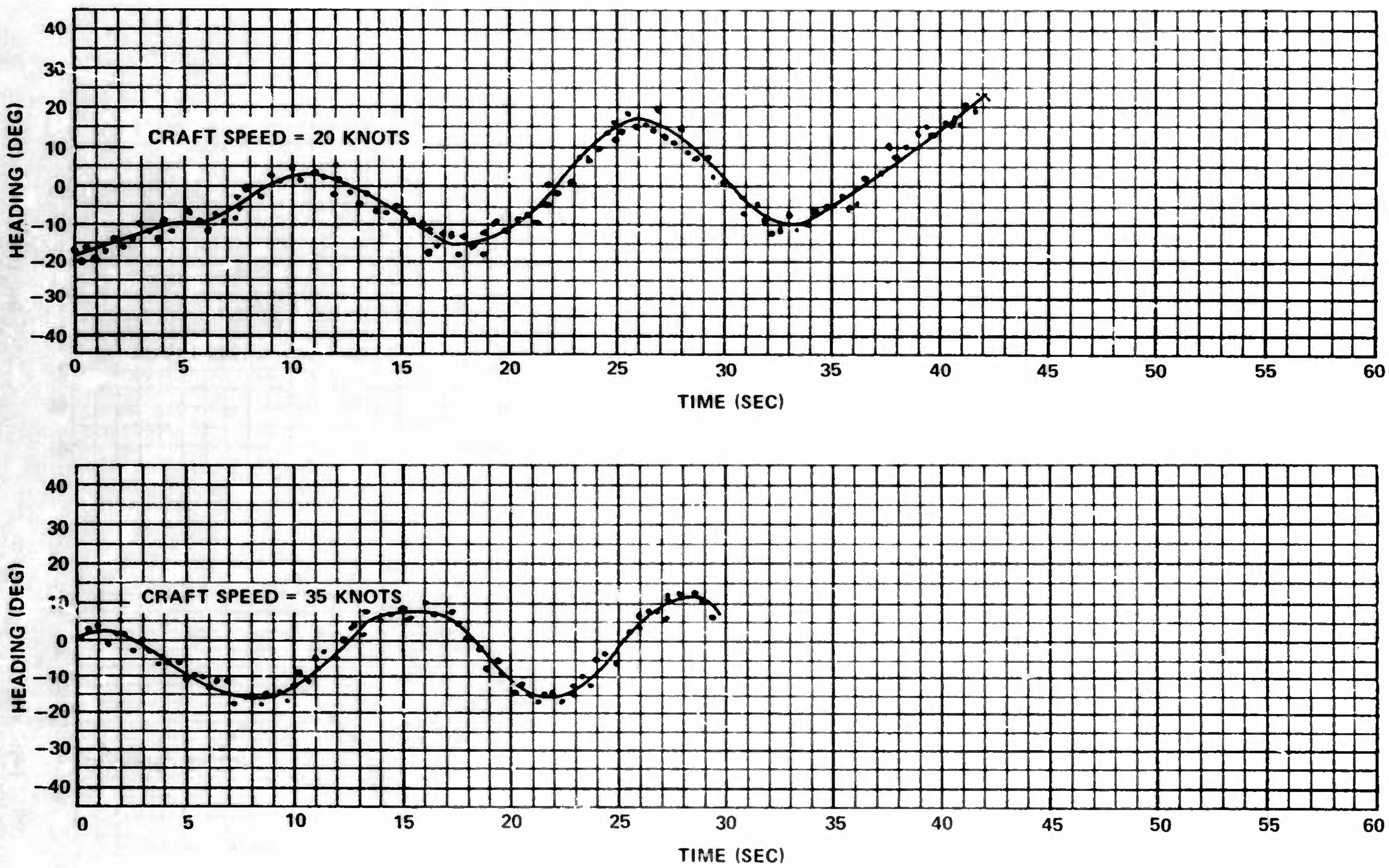


Figure 50 – Variation in Craft Heading with Time for Puff Port Actuation

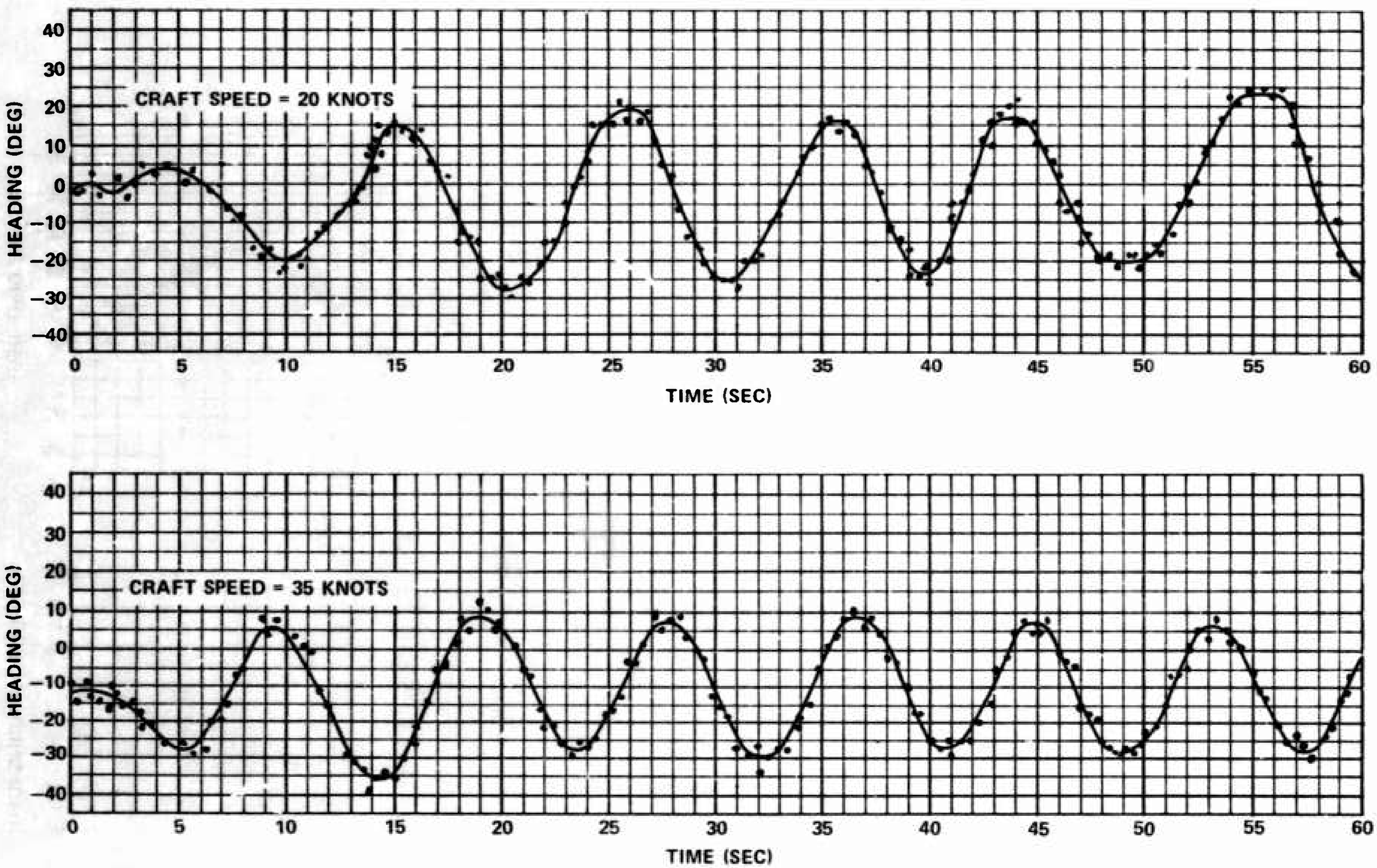


Figure 51 – Variation in Craft Heading with Time for Combined Actuation of Rudder and Puff Port

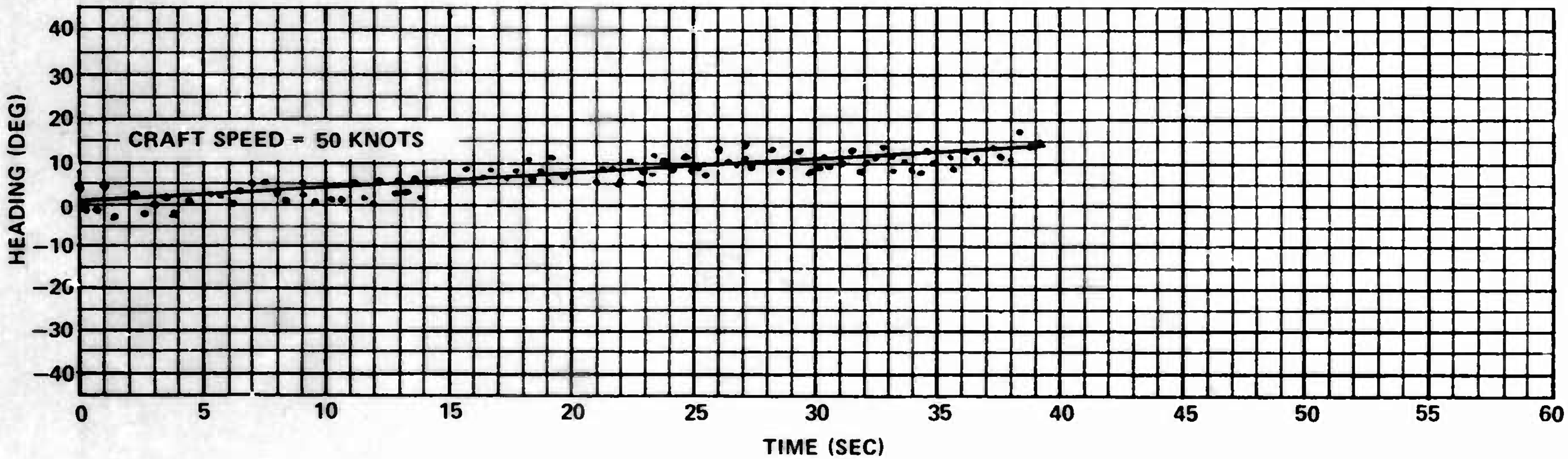


Figure 52 – Variation in Craft Heading with Time for Skirt Lift Actuation

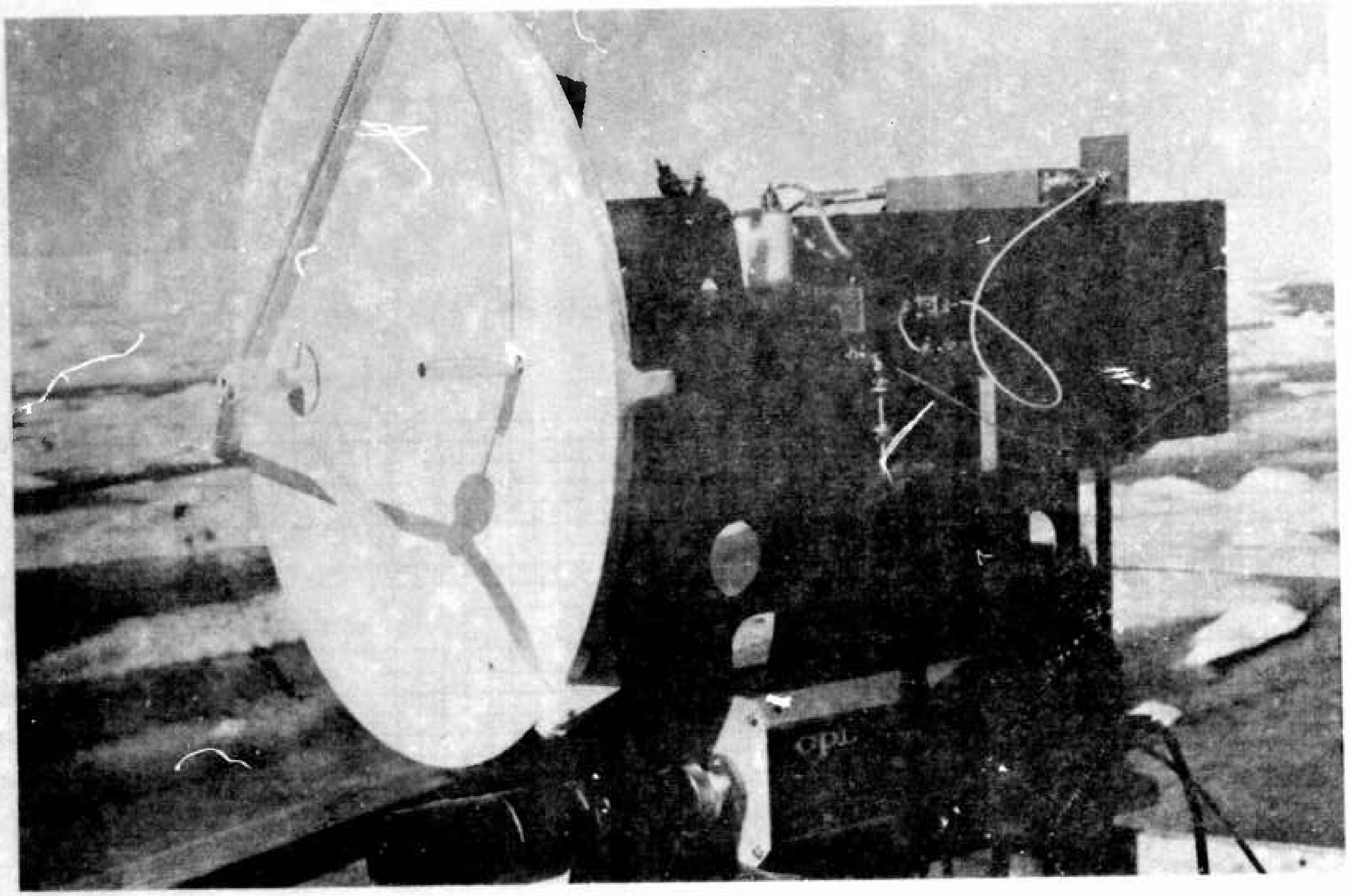


Figure 53 – 1.06-Micron Laser and 94-GHz Radar for June Terrain Sensing Studies

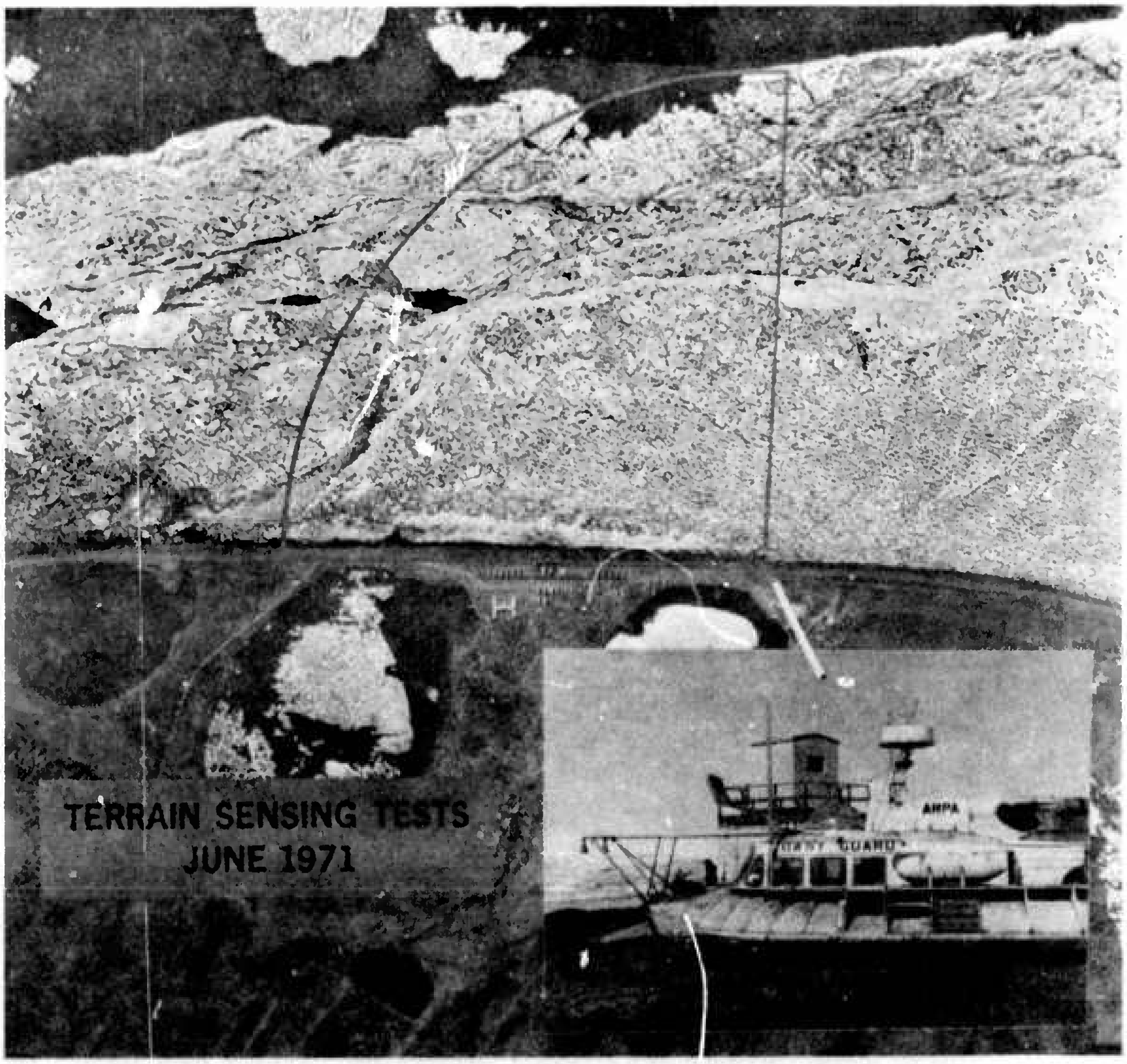


Figure 54 – June Test Site for Terrain Sensing Studies

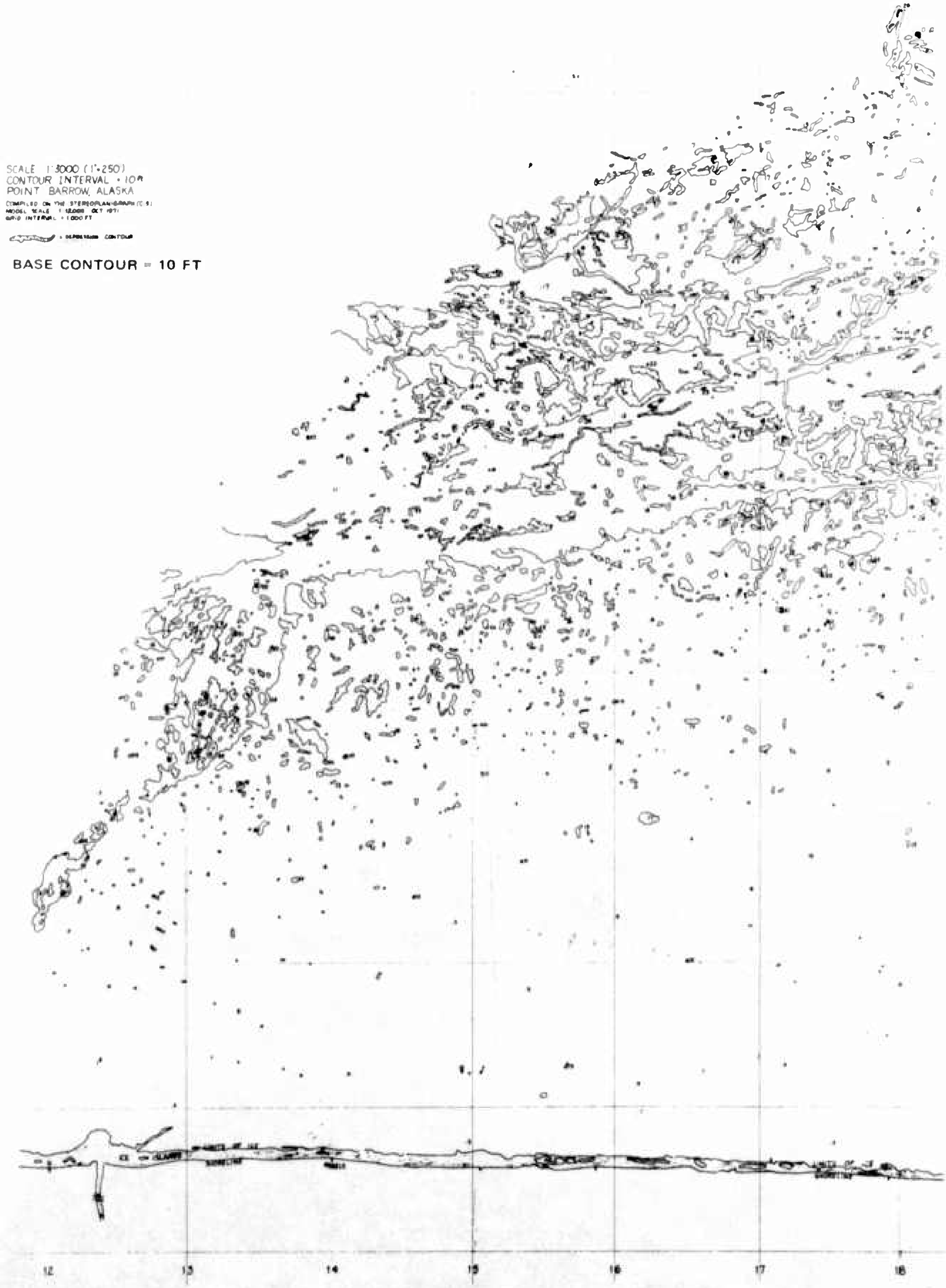


Figure 55 – Ground Truth Data from Terrain Sensing Studies

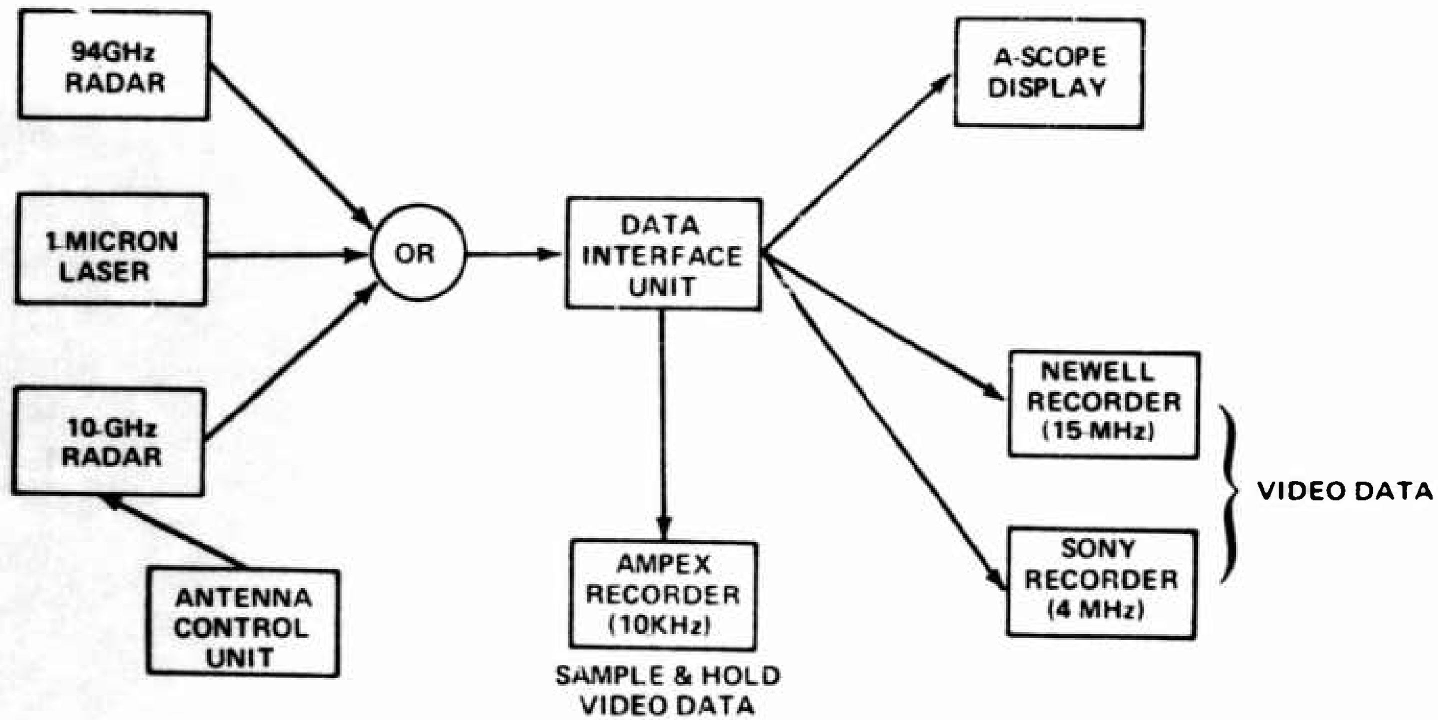


Figure 56 — Basic Test Configuration for Terrain Surveillance Tests

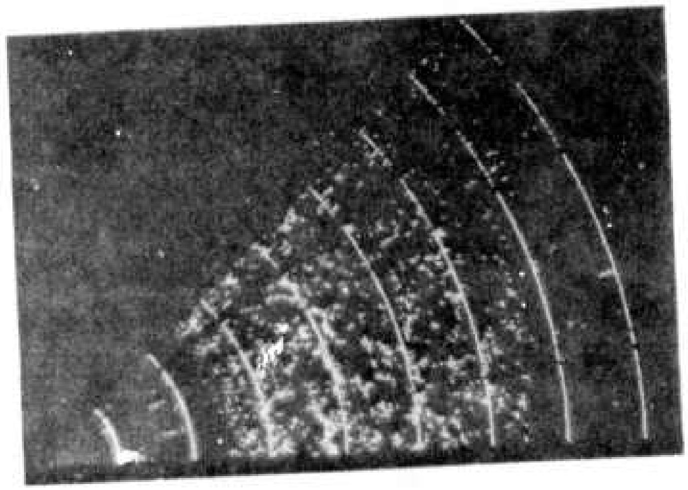


Figure 57 – Sample Return (94-GHz Radar and 1.06-Micron Laser)

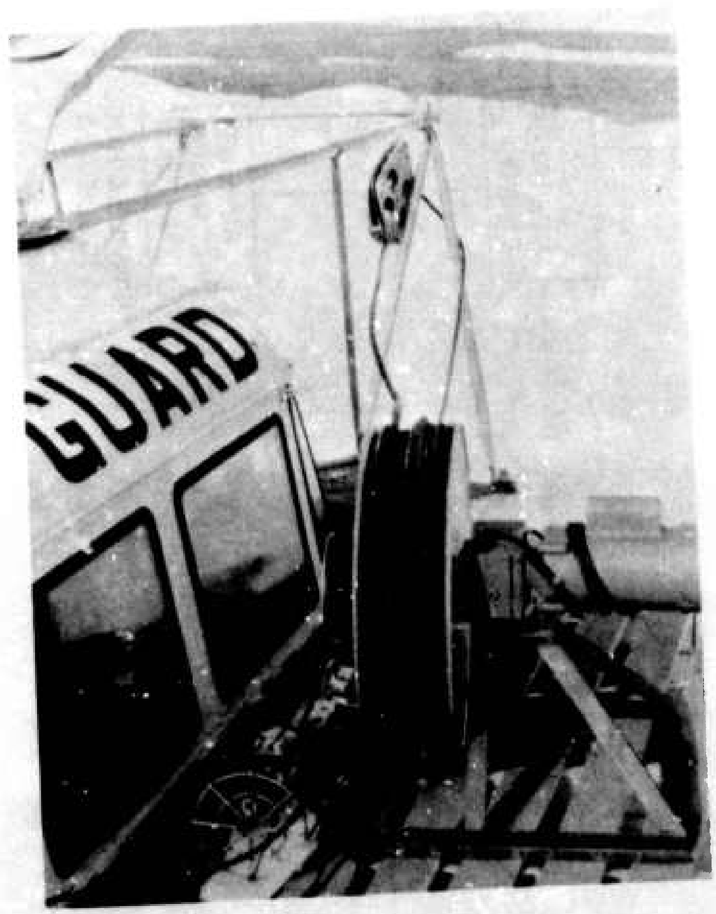


Figure 58 – Data Acquisition System for 1971 Marginal Ize Zone Studies

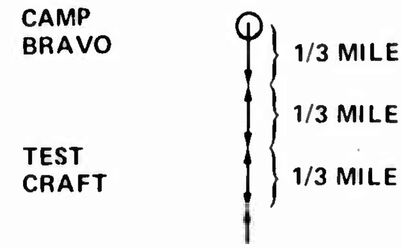


Figure 59a – Fine Grid–Test Craft Perform S.T.D. Measurements

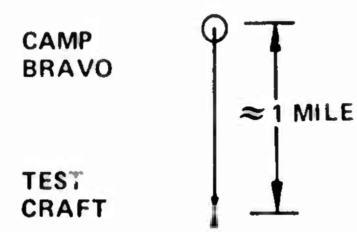


Figure 59b – Acoustic Grid–Test Craft to Obtain Acoustic Data Every Hour

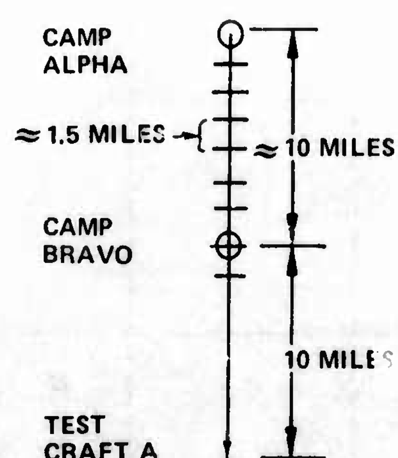


Figure 59c – Coarse Grid–Test Craft to Start at A and Obtain Test Data Every Mile Until it Reaches Camp Alpha

Figure 59 – Trial Courses for 1971 MIZ Studies

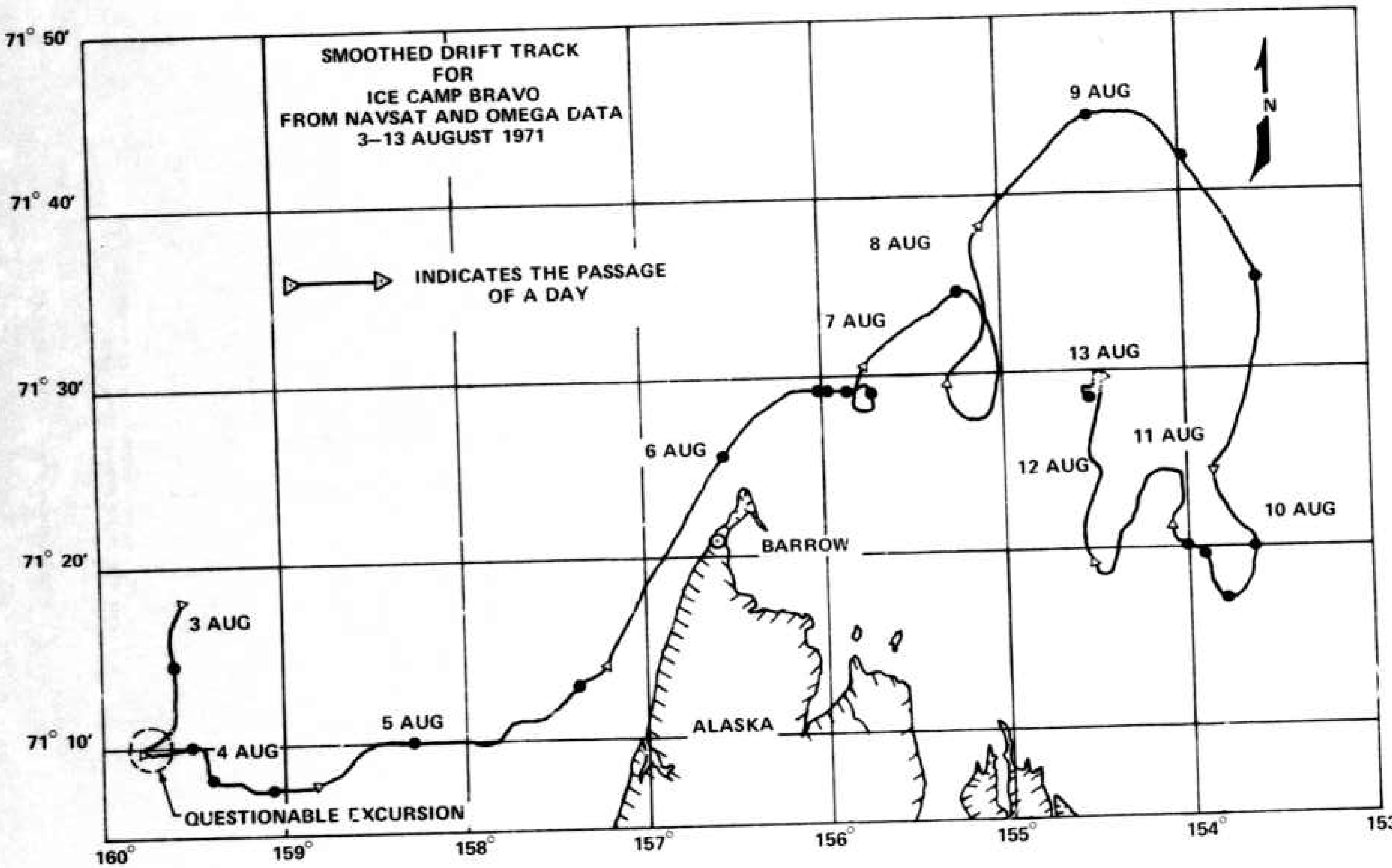


Figure 60 – Drift Track of Ice Floe during 1971 MIZ Studies

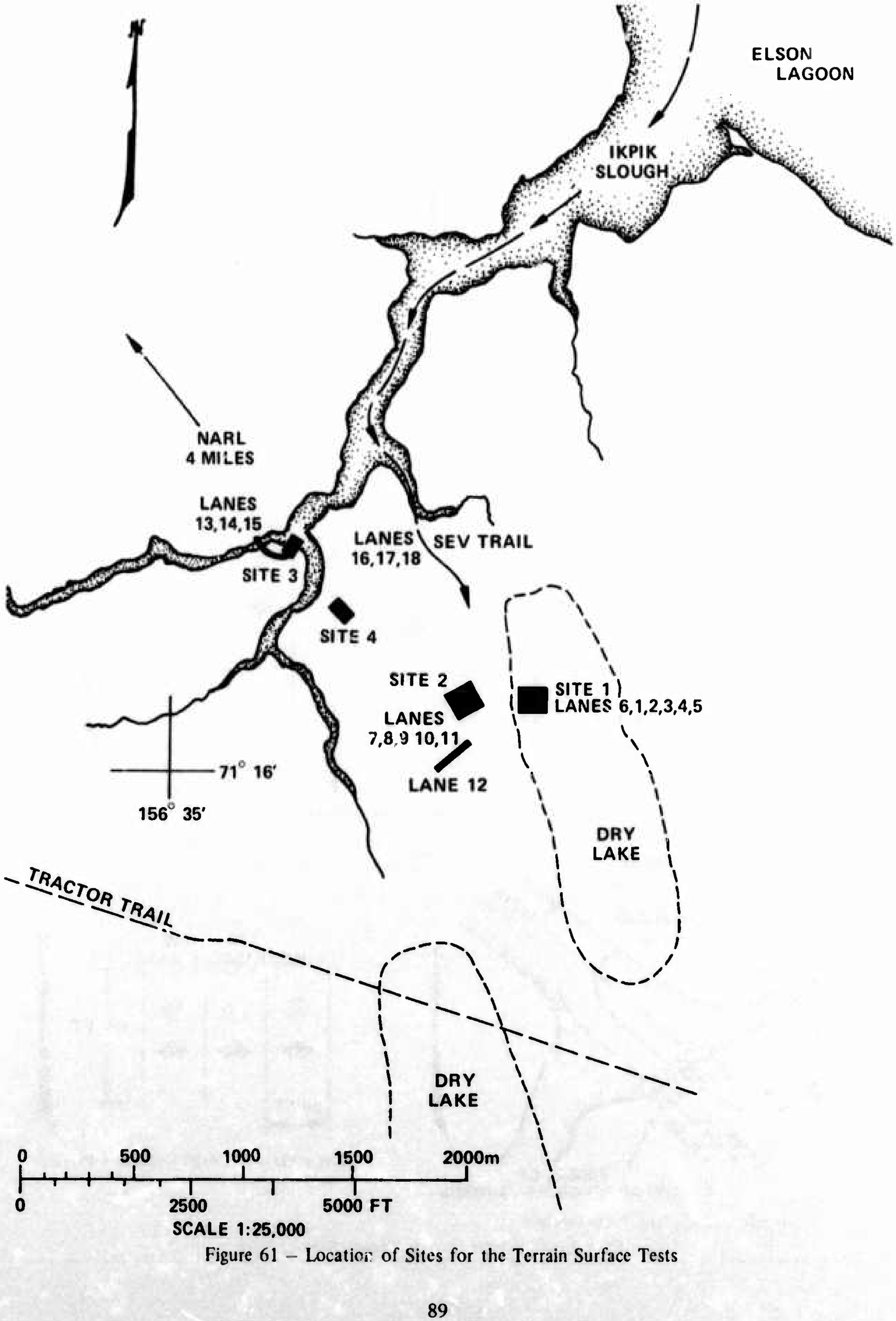


Figure 61 – Location of Sites for the Terrain Surface Tests

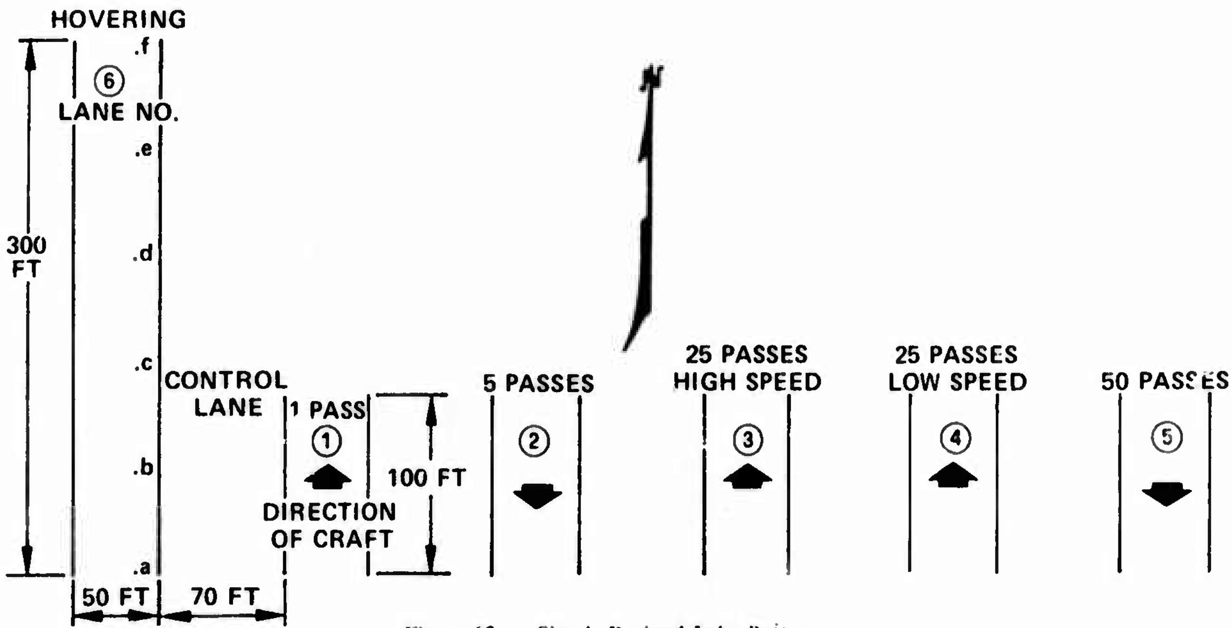


Figure 62a – Site 1, Drained Lake Bottom

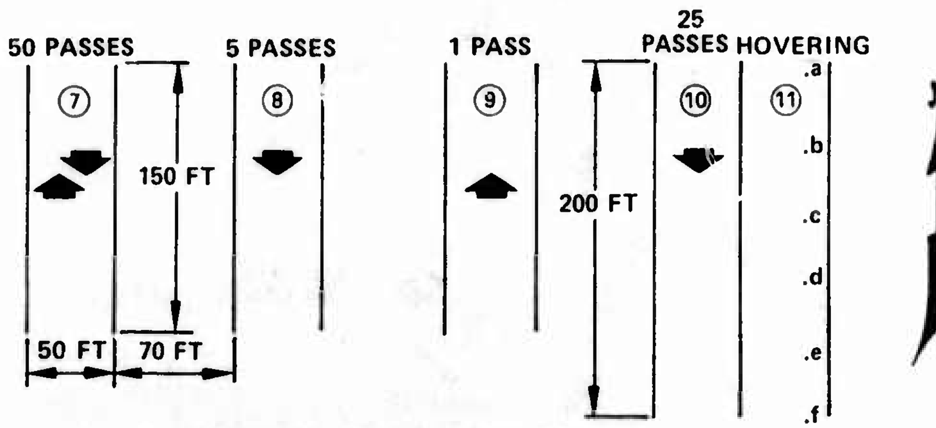


Figure 62b – Site 2, Low Centered Polygons

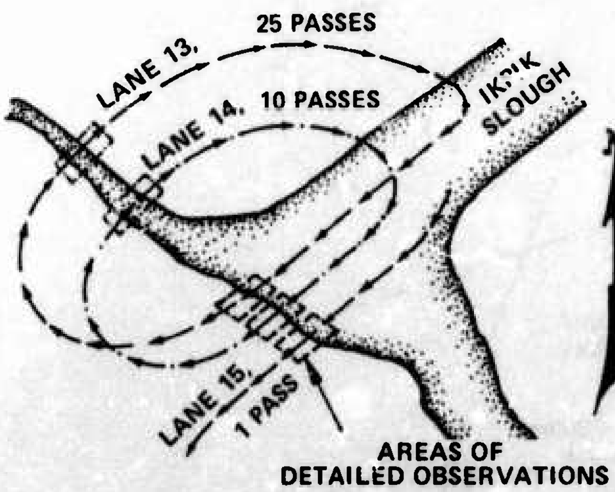


Figure 62c – Site 3, Land-Water Interface

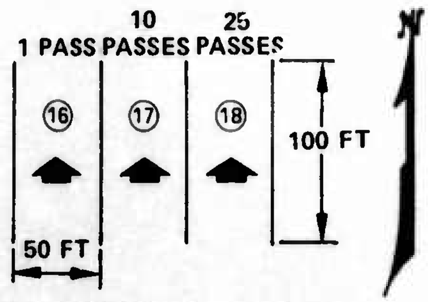


Figure 62d – Site 4, High Centered Polygons

Figure 62 – Lane Layouts for the Terrain Surface Tests

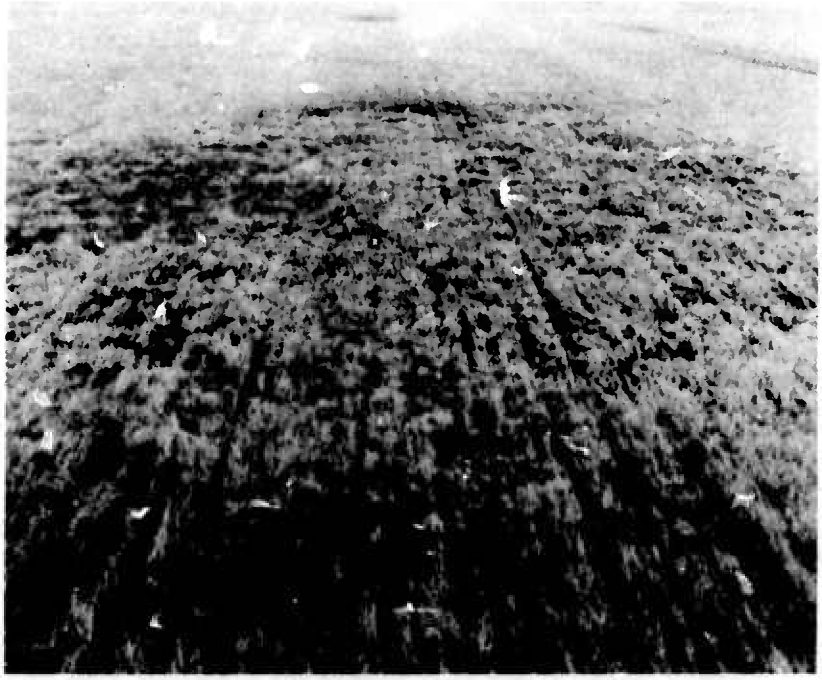


Figure 63a – Site 1, Lane 3, after 25 Passes at High Speed

Figure 63b – Site 1, Lane 4, after 25 SEV Passes at Low Speed

Figure 63 – Effect of Vehicle Speed on Terrain Degradation

Figure 64a – Site 1, Lane 6, after 10 Minutes of Hovering (No Skirt Drag)

Figure 64b – Site 1, Lane 1, after One SEV Pass at 35 MPH

Figure 64 – Visible Effects on Terrain from 10 Minutes of Hovering and One High-Speed SEV Pass

Figure 65a – Site 1 after One Pass with Test Craft

Figure 65b – Site 1 after One Pass with Weasel

Figure 65 – Visible Effects on Terrain from SEV and Weasel Transit

Figure 65c – Site 1 after 25 Passes with Test Craft

Figure 65d – Site 1 after 25 Passes with Weasel

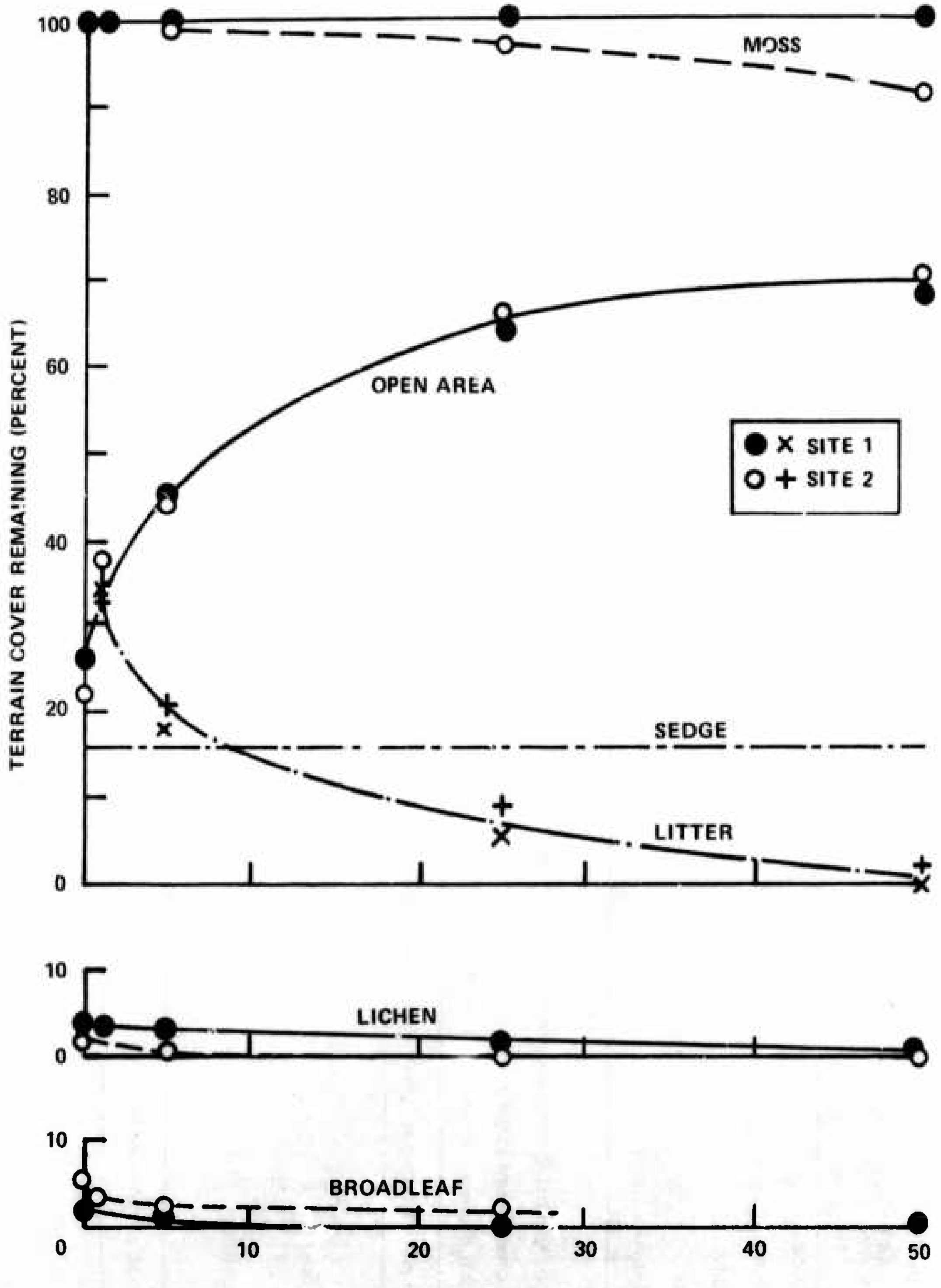


Figure 66 – Effect of Repeated SEV Traffic on Various Types of Arctic Vegetation
(Data from Rickard[32])

TABLE 1 – TEST CRAFT SPECIFICATIONS

(Modifications by Bell Aero Systems, Buffalo, New York)

Dimensional Data:	
Overall Length	38 ft, 9 in.
Overall Width	23 ft
Overall Height	16 ft, 6 in.
Cushion Clearance Height	3 ft, 6 in.
Power:	
Engine Type: General Electric gas turbine, Model 7LM100-PD101	
Lift: 7-ft-diameter centrifugal fan	
Propeller: 9-ft-diameter, three-bladed, variable pitch	
Weight:* Normal operating at Barrow	17,818 lb
Performance:	
Maximum Speed	70 mph (fullup weight)
Range	250 nm
Fuel consumption	60 gal/hr
Endurance	4 hr

*See pages 43–46 of Reference 16.

TABLE 2 – WEEKLY CRAFT OPERATING AND MAINTENANCE HISTORY

Period	Maintenance man hours	Engine Operation hours
26 - 31 March	132.2	
1 - 8 April	166.7	5.6
9 - 16 April	225.0	0
17 - 23 April	156.0	0
24 - 30 April	92.0	0
1 - 8 May	191.0	1.8
9 - 16 May	3.5	22.5
17 - 23 May	0	12.5
24 - 31 May	15.0	6.7
1 - 8 June	66.1	24.8
9 - 16 June	121.5	11.9
17 - 23 June	74.0	5.2
24 - 30 June	51.5	0
1 - 8 July	50.0	3.9
9 - 16 July	69.0	23.4
17 - 23 July	75.3	34.8
24 - 31 July	191.9	3.6
1 - 8 August	62.8	26.8
9 - 16 August	92.7	14.3
17 - 23 August	116.5	14.2
24 - 28 August	64.0	14.7
TOTAL	2019.7	226.7

TABLE 3 — SEV MAINTENANCE HISTORY DURING 1971 ARCTIC TEST PROGRAM

A. UNSCHEDULED MAINTENANCE ON CRAFT SUBSYSTEMS (total: 1031.0)	Man-Hours
Engine and Accessories	123.0
Radar and Navigation	93.0
Structures	22.5
Fuel and Lubrication Systems	9.5
Hydraulic System	9.6
Electrical System	22.0
Communications Equipment	103.0
Propeller	67.8
Skirts and Air Bags	401.7
(a) Fingers	110.5
(b) Hinges and Chains	112.2
Controls	2.0
Heating and Ventilation	26.0
Skids	3.0
Puff Ports	17.0
Rescue and Survival	0.5
Cabin and Windshields	77.5
Auxiliary Power Unit	3.4
Transmission	8.0
Miscellaneous Craft Maintenance	41.5
Ratio Unscheduled Arctic Maintenace on Craft to Operating Hours (Man-Hours/Hour)	4.59
B. SCHEDULED CRAFT MAINTENANCE (total: 203.2)	
Cleaning of Craft	35.0
Handling of Craft	96.2
Inspection – 100 Hour Engine (2)	72.0
Ratio Scheduled Maintenance to Operating Hours (Man-Hours/Hour)	0.896
C. OTHER CRAFT MAINTENANCE (total: 785.5)	
Craft Assembly	105.0
Damage Repair on Craft Sidebody	639.0
Craft Disassembly	41.5
Ratio Other Craft Maintenance to Operating Hours	3.43
Total Craft Arctic Maintenance	2019.7
Ratio Total Craft Maintenance to Operating Hours	8.91
Ratio Damage Repair to Operating Hours (Man-Hours/Hour)	2.78

TABLE 4 – TEST CRAFT MOMENTS OF INERTIA AND WEIGHT

Craft Weight, lb:

Craft dry weight (including skirts)	13,614
Fuel	1,910
Crew	720
	16.244

Craft Moment of Inertia, slugs-ft^2 (Dry Weight)

I_{xx} = 13,430

I_{yy} = 38,740

I_{zz} = 40,920

I_{xz} = 1,770

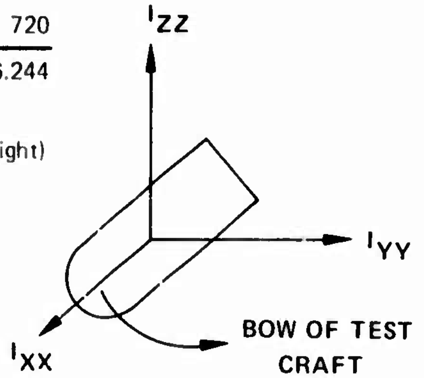


TABLE 5 – UNDERWAY FREQUENCIES GENERATED BY MACHINERY ON TEST CRAFT

Source	Frequency, Hz		
	50% Power	80% Power	100% Power
Fan Rotational	7.4	11.8	14.8
Propeller Shaft Rotational	15.5	25	31
Propeller Blade	62	100	124

TABLE 6 – RESONANT FREQUENCIES ON TEST CRAFT

Frequency Hz	Resonance Location	Type of Mode	Shaker Location
8.5	Stern vertical	Indeterminate	Nacelle vert.
13.5	Both nacelle athwartship gages	Nacelle Yaw I	Nacelle and both athw.
13.7	Bow and stern vertical gages	Two-noded hull bending	Bow and nacelle vert.
14.3	Bow athwartship	Indeterminate	Nacelle vert.
15.0	Both nacelle athwartship gages	Indeterminate	Nacelle athw.
19.7	Nacelle aft end	Nacelle pitch	Bow and nacelle vert.
20.5	Bow and stern athwartship	Indeterminate	Bow athw.
24.4	Both nacelle athwartship gages	Nacelle Yaw II	Bow and nacelle athw.
27.6	Propeller blade tip	Blade bending	Hammer blow on blade
30.8	Propeller blade tip	Blade bending	Hammer blow on blade
33.0	Buoyancy tank vertical	Rigid body rotation about hinge points	At all location
37.0	Bow and stern athwartship	Indeterminate	Bow athw.
46	Stern athwartship		Bow athw.
50	Nacelle forward vertical		Bow vert.
65	Stern vertical		Nacelle vert.
74	Midships vertical	Indeterminate	Nacelle vert.
82	Buoyancy tank vertical	Local at gage	bow vert.
101	Midships longitudinal	Local at gage	bow athw.
135	Midships athwartship	Local at gage	bow athw.
166	Stern vertical	Local at gage	bow athw.

TABLE 7 – COMPARISON OF THE MEASURED AND CALCULATED TOTAL PRESSURE DEVELOPED BY THE SEV LIFT FAN

(Average absolute deviation = 2.5 percent; mean calculated pressure loss = 11.7)

Craft Weight lb	Fan Speed rpm	Measured Skirt Pressure lb/ft^2	Calculated Pressure Loss lb/ft^2	Calculated Fan Total Pressure lb/ft^2	Measured Fan Total Pressure lb/ft^2	Deviation percent
12,000	708	32.3	9.8	42.1	42.5	–0.9
	753	34.3	9.3	43.6	44.5	–2.0
	795	37.0	10.2	47.2	49.3	–4.3
	840	39.5	11.5	50.0	51.5	–2.9
	885	43.5	12.0	55.5	57.0	–2.6
15,000	708	39.5	11.2	50.7	48.0	+5.6
	753	42.0	12.0	54.0	52.5	+2.9
	795	43.5	12.5	56.0	55.5	+0.9
	840	45.0	12.8	57.8	58.0	–0.3
	885	47.0	13.7	60.7	62.5	–2.9
18,000	708	40.0	11.8	51.8	49.5	+4.6
	753	41.0	11.3	52.3	50.5	+3.6
	795	43.5	12.4	55.9	55.0	+1.6
	840	45.0	12.9	57.9	58.5	–1.0
	885	46.5	11.8	58.3	58.0	+0.5

TABLE 8 – CRAFT CHARACTERISTICS FOR THE DECELERATION TESTS OVER TUNDRA

(Method 1 utilized propeller pitch reversal and Method 2 piroutte with maximum positive propeller pitch)

Deceleration Method	Initial Speed knots	Percent Power (rpm)		Initial Prop Pitch deg	Time sec	Distance ft
		Computed	Turb			
1	20	85	86	5	28	605
	25	86	85	8	30	735
	37.5	88	88	8	32	1055
	42	92	92	8	36	1275
1	24.5	85	86	5		450
2	28	86	85	8		520
2	35	88	88	8		655
2	40	92	92	8		745

TABLE 9 – CRAFT CHARACTERISTICS FOR THE DECELERATION TESTS OVER SNOW

(Method 1 utilized propeller pitch reversal and Method 2 piroutte with maximum positive propeller pitch)

Deceleration Method	Initial Speed knots	Percent Power (rpm)		Initial Prop Pitch deg	Time sec	Stopping Distance ft
		Computed	Turb			
1	10	83	83	5	12	115
	12	85	86	5	13	115
	15	88	88	8	14	215
	25	92	92	8	17	385
	35	95	95	14	21	635
	10	83	83	5		140
1	12	85	86	5		120
2	16	88	88	8		220
2	27	92	92	8		480
2	35	95	95	14		640

TABLE 10 – TEST CONDITIONS AND RESULTS FOR SKIRT DRAG OVER SNOW

(Letter designations UW and DW respectively indicate upwind and downwind)

Run No.	Course	Percent Power (rpm)		Prop Pitch deg	Average Velocity ft/sec
		Computed	Turb		
60101	Prepared Snow (UW)	90	90	10	52.9
60102		85	85	3	62.7
60103		95	95	16	73.2
60104		85	80	8	71.5
60105	Prepared Snow (UW)	90	90	9	46.6
60106	Natural Snow (DW)	85	85	3	51.1
60107	Natural Snow (UW)	95	95	16	70.3
60108	Natural Snow (DW)	85	80	8	65.0

TABLE 11 – TEST CONDITIONS AND RESULTS FOR SKIRT DRAG OVER TUNDRA

Run No.	Course	Percent Power (rpm)		Prop Pitch deg	Average Velocity ft/sec
		Computed	Turb		
82101	Dry Lake Bed	90	90	10	43.0
82102		85	85	4	20.8
82103		95	95	16	50.5
82104		85	80		48.5
82105	Dry Lake Bed	90	90	10	61.2
82106	Natural Tundra	85	85	4	35.4
82107	Natural Tundra	95	95	16	73.3
82108	Natural Tundra	85	80	8	48.6

Note: The magnitude of the average velocity indicates a discrepancy in the initial propeller pitch; this could not be verified due to a failure of the measuring instrumentation.

TABLE 12 – TOTAL THRUST, AERODYNAMIC DRAG, AND SKIRT DRAG CALCULATED FROM THE TWO THRUST PREDICTION METHODS

(All data are in pounds and are given with reference to smooth ice)

Run No.	Total Thrust (Ref. 3)	Total Thrust (Ref. 4)	D_{Aero} (Ref. 3)	D_{Aero} (Ref. 4)	D_{Skirt} (Ref. 3)	D_{Skirt} (Ref. 4)
Smooth Ice						
60101	1000	1395	560	955	–	–
60102	308*	680	–	420	–	–
60103	1793	2060	893	1165	–	–
60104	674	995	274	595	–	–
Rough Ice						
60105	945	1330	–	–	110	160
60106	443	710	–	–	150	190
60107	1830	2100	–	–	400	420
60108	744	1020	–	–	265	260
Dry Lake Bed						
82101	1175	1503	–	–	495	515
82102	557	798	–	–	265	275
82103	2143	2380	–	–	1300	1210
82104	–	–	–	–	–	–
Tundra						
82105	912	1361	–	–	−130	−60
82106	388	764	–	–	−120	−40
82107	1847	2113	–	–	+460	+413
82108	602	963	–	–	−120	−70

*This low valve probably indicates an error in the prediction method for this particular propeller angle (3 deg).

TABLE 13 – SEV PARTICIPATION IN 1971 MARGINAL ICE ZONE STUDIES

(August 1971)

1 Transient NARL to Ice Floe	2 Logistic Support	3 Coarse Grid	4 Logistic Support	5 Acoustic Grid	6 Coarse Grid	7 Fine Grid Logistic Support
8 Logistic Support	9 Coarse Grid	10 Fine Grid at Camp ALPHA	11 Acoustic Grid	12 Acoustic Grid	13 Coarse Grid	14 Transient Ice Floe to NARL

APPENDIX A

ROLES OF THE PARTICIPATING ACTIVITIES

NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER

NSRDC was designated by ARPA as the Technical Program Management Organization for the Arctic SEV Program.

NSRDC assumed the following responsibilities while participating in the ARPA 1971 Arctic Trials at NARL, Point Barrow, Alaska:

1. Plans for and execution of the technical program to accomplish the test objective, including periodic redirection as required.

2. Coordination (with NARL) on all aspects of the test program including support and logistics.

3. Coordination of the activities of all civilian personnel assigned to the test program.

4. Selection of test and operational sites.

5. Design changes, repairs, and modifications to the data acquisition system.

6. Collection and analysis of data.

7. Maintenance of technical data relating to the test program, including data on certain craft subsystems.

8. Provision of an on-site Test Director to coordinate and direct the technical aspects of the test program and assume responsibility for the overall conduct of the tests.

9. Coordination for implementation of the trials agenda to ensure the maximum utilization of the test craft.

APPLIED PHYSICS LABORATORY JOHNS HOPKINS UNIVERSITY

APL/JHU was responsible for developing suitable communication, navigation, collision avoidance, and terrain surveillance equipment for the Arctic SEV Program. More specifically, APL/JHU was responsible for the following aspects of the 1971 Arctic trials for the ASEV Program.

1. A series of terrain sensing experiments to determine the most effective technique for measuring the vertical extent of obstacles. This included the collection of video recordings from typical Arctic terrain under a variety of conditions using an X-band radar, a 94-gHz radar, and an extremely narrow-beam ranging laser.

2. Collection of magnetic tapes of recorded data and their shipment to APL for dubbing and storage.

3. Operation, maintenance, and repair of the data acquisition instrumentation system.

U. S. ARMY COLD REGION RESEARCH AND ENGINEERING LABORATORY

CRREL provided data on the Arctic environment to the ASEV Program and is responsible for evaluating the environmental and ecological aspects of SEV operations in the Arctic. CRREL was responsible for carrying out the following assignments in conjunction with the 1971 Arctic trials program:

1. Determination of the extent and rate of terrain surface erosion together with the damage to vegetation from the action of the air cushion and the peripheral air jet curtain.

2. Investigation of the effects of terrain surface porosity on the capability of an ASEV to maintain an air cushion together with any other noteworthy influence on test craft operation.

UNITED STATES COAST GUARD AIR CUSHION EVALUATION UNIT

The Air Cushion Evaluation Unit of the United States Coast Guard (USCG) was responsible for operating and maintaining the test craft. It was assigned the following tasks in conjunction with the 1971 Arctic trials:

1. Final authorization on the execution of each particular mission.

2. Maintenance of communications equipment and assurance of positive communications at all times between the operating test craft, base, and support craft.

3. Provision of Coast Guard advisory assistance if required.

4. Arrangments for complete and timely information on craft operational status.

5. Acquisition of weather and environmental data for use in daily test planning.

6. Maintenance of daily logs on craft operation.

7. Maintenance of an operating crew to support the test program.

8. Provision of service and maintenance for the test craft in support of the trials.

9. Establishment of operational requirements and procedures for the test craft consistent with mutually agreed policy of the Local Operation Area Commander and the Director of NARL.

AEROSPACE CORPORATION

ARPA designated the Aerospace Corporation to assist NSRDC in technology management and planning activities, as required. For the 1971 Arctic trials, Aerospace was responsible for preparing the transportation plan to airlift the test craft and its support equipment from NAS Alameda to Barrow, Alaska.[6]

UNITED STATES AIR FORCE

The United States Air Force (22nd Air Force, Travis Air Force Base, California) airlifted the test craft and associated cargo to and from Barrow. The USAF C-133 flew the test craft and cargo to NARL. It was the largest aircraft to land at Barrow as of that date (March 1971).

APPENDIX B

SPECIFICATIONS FOR REFURBISHING AND WINTERIZING THE TEST CRAFT

(ACV 03, Navy Serial 02, Serial 015)

The test craft (ACV 03, Serial 017) was prepared for the February–August 1971 Arctic SEV trials at the Oakland (California) facility of Transportation Technology, Inc.

REFURBISHMENT

The following specifications represent the extent of the test craft refurbishment prior to deployment in the Arctic:

Side Deck, Starboard Side:

a. Remove and renew the first boundary member at the bow and replace the skin in the first panel.

b. Replace deformed splice plate at vertical attachment on side deck to main side beam at B.L. 48. Replace all missing or loose rivets. Replace all loose, missing, or stripped bolts.

c. Clean entire surface area of corrosion, loose paint, grease, and other debris. Replace all loose or missing rivets. Paint in accordance with painting specifications.

d. Renew first hat section with Government-furnished material.

e. Install approximately 12 to 14 ft of new channel on deck where missing. Replace all missing, corroded, or rusted holddown bolts. Remove cleats port and starborad; replace with cast aluminum 8 in. cleats, Perko Figure 545 or equal. Remove all nonskid paint in accordance with painting specifications.

f. Strip jagged edges of former auxiliary tank supports at boundary member. Paint in accordance with painting specifications.

g. Remove panel over forward and aft puff ports for inspection. Clean up corrosion and paint interior of puff port in accordance with painting specifications. Replace panel.

h. Replace all missing, stripped, or loose bolts, rivets, and spacers on the horizontal attachment of side deck on main side beam at B.L. 48.

Side Deck, Port Side:

a. Renew bent and cracked boundary member, Frames 1 and 2.

b. Renew bowed boundary member at Frames 9 and 10.

c. Remove ladder hinge brackets (brackets no longer required).

d. Renew and replace approximately 30 ft deck channel. Replace several missing, corroded, or rusted bolts. Paint in accordance with painting specifications.

e. Renew jagged and bent hat section Government-furnished on all plenum access door, lower longitudinal.

f. Remove panel over forward and aft puff ports for inspection. Clean up corrosion and paint interior of puff ports in accordance with painting specifications. Replace panels.

g. Install Government-furnished longitudinal rib for deck platform missing from Frames 5 and 6.

h. Renew skin section between Frames 8 and 9.

i. Clean up surface corrosion, loose paint, firt, and other debris on all panels of side deck; replace all loose or missing rivets. Paint in accordance with painting specifications.

j. Replace all loose or missing bolts, rivets, and spacers on the horizontal attachment of side deck to main side beam at B.L. 48.

Bow Section:

a. On starboard side of bow section, renew bent edge member and buckled top panel skin with a 10- by 15-in. patch.

b. Renew bent hinges on access door.

c. Renew all wooden strips around access door.

d. Remove, clean, adjust, and reinstall latch mechanism for access door. Clean corrosion and paint in accordance with painting specifications herein.

e. Remove port and vertical web brackets (no longer required).

f. On starboard vertical side wall of bow opening, replace damaged skin upper corner approximately 10 x 10 in. Remove fire extinguisher bracket and armor plate fittings and fill holes with blind rivets. Clean all aluminum surface of corrosion; paint in accordance with painting specifications.

g. Remove and renew approximately 5-ft-long angle at forward end of damaged stiffener on ramp.

Cabin Door:

a. Install new hold-open mechanism on bow door. Clean and realign door and window for proper fit. Install new seals, and door springs along with bolts and brackets. Remove, clean, and reinstall corroded windshield wiper base plate. Paint in accordance with painting specifications.

Bow Ramp and Cabin Deck:

a. Remove buckled skin on bow ramp and install two small patches.

b. Remove and renew damaged stiffeners in bow ramp.

c. Remove nonskid paint. Remove two tripod gun mounts and plug holes with epoxy material. Attach patch plates over holes and blind rivet using EC-1239 sealant or equal. Clean entire deck surface and paint in accordance with painting specifications.

d. Before laying any deck coverings, ensure deck is smooth, dry, free of foreign matter, and not be unduly hot or cold. During this process, protect new work from damage with temporary covering. Cover cabin and deck ramp with fire-retardant grey rubber matting having a diamond tread pattern in accordance with MIL-M-15562. Ensure covering extends under built-in furniture or equipment. Secure the matting to the decks with waterproof cement that is compatible with both fiberglass and rubber.

Skirt Attachment Structure:

a. Remove and renew all hinge pins. Renew all missing or bent hinges and bushings.

Forward Hoist and Aft Tow Fittings:

a. Remove. Fabricate similar fittings using Type 316 stainless steel and reinstall using neoprene gasket between fitting and deck.

Nacelle Struts:

a. Remove and install new nacelle struts and bolts. Paint in accordance with painting specifications

Exterior, Aft of Cabin:

a. Renew all sheet metal on air inlet cowling, Frame 7 and 8 starboard side. Paint in accordance with painting specifications.

b. Replace all wooden battens on top of air intake cowling for walkway, Frame 7 and 8 port side.

c. Remove all armor plate and brackets. Plug all rivet holes with blind rivets throughout the craft where armor has been removed.

d. Renew all engine–cowl rubber seals.

e. Renew all bolts for lift fan guard.

f. Move propeller guard 8 in. forward on port and starboard sides of side decks. Plug old holes with blind ivets.

g. Remove gun turret and all associated equipment including gun ring.

h. Install suitable Lexan or aircraft-grade plexiglass bubble over opening to make bubble watertight.

i. Remove equipment box on cabin roof port side, and plug all holes.

j. Repair all handrails on port and starboard side of cabin roof.

k. Fabricate and install a new radar pedestal generally similar to the present pedestal but using 1/4 in. 5086 alloy aluminum plate. The pedestal shall be compatible with radar antenna specified elsewhere herein, and with a mounting bracket for a forward navigation light at leat 9 ft above the boundary.

l. Install navigation lights in compliance with International Rules of the Road as follows: A forward navigation light, Perko Figure 1279 or equal, on the radar pedestal and a stern light, Perko Figure 1280 or equal, on the starboard vertical stationary rudder. Connect both lights to the present switch for side lights.

m. Remove the amber shade from the rotating light on the port vertical stationary rudder and replace with a blue shade. Disconnect wiring from navigation light switch and install and connect a new, separate switch on the driver's panel. Clean and place rotating mechanism in proper operating condition.

n. Remove, clean, and repair existing side navigation lights. Reinstall and repair fiberglass mountings.

Empennage:

a. Repair 1 1/2 in.-diameter hole in forward section of Bondalite deck.

b. Renew with Government-furnished material the top and bottom elevators.

c. Remove all corrosion on rudders, port and starboard bleed ducts, elevator, and entire tail assembly. Replace all missing holddown bolts on port and starboard rudder bleeds. Paint in accordance with painting specifications.

d. Repair 5 in. hole on inboard side bottom port rudder bleed duct.

e. Replace two missing stiffeners with Government-furnished port rudder bleed duct.

f. Repair 1/2 in. hole outboard halfway up port rudder.

g. Repair fiberglass trailing edge of rudder bleed on port rudder, 12 in. long.

h. Straighten trailing edge of starboard rudder.

i. Repair fiberglass trailing edge of rudder bleed on starboard rudder 18 in. long.

j. Replace missing stiffener, Government furnished, in starboard rudder air bleed duct.

k. Repair small area bottom starboard rudder air bleed duct caused by towline chaffing.

Cabin Interior:

a. Renew port and starboard windshields, radar operator and driver side windows, and two half windows. Install two new windows at former gunner station, hinged so windows may be opened inboard. Reseal all windows with new rubber seals.

b. Replace all missing or broken locknut fasteners on covers for battery electrical bay.

c. Remove all ammunition boxes, racks, and brackets.

d. Remove armor plate and bracket forward at instrument panel, and plug all holes with blind rivets.

e. Remove, clean, and refurbish driver and radar operator seat frames, and renew seat and back covers. Reinstall seats.

f. Remove corrosion and repair as necessary all radar support structure and renew all Lord mounts.

g. Install bottom covers on driver and radar operator overhead panels.

h. Install insulating blanket quilted Type I with porous trim cloth on overhead, sides, and after bulkhead of cabin. Use a nonspecular gloss, AN color 620 light grey per MIL-I-7171C. Secure the insulating blanket to the craft with Velcro tape, manufactured by Hartwell Corporation. The insulating blanket material may be purchased as F417/1 from Flightex Fabric Corporation, New York, N.Y.

i. Install external cabin heater of Southwind type capable of operating on JP-4 or JP-5 fuel. Heater capacity to be not less than 24,000 BTU/hr. Stuart Warner 940F24, or equal, type heater acceptable.

j. Install fore and aft Vista-Cruiser type back-to-back seats on port and starboard sides of cabin. Seats to extend from after cabin bulkhead, longitudinally, to rear of driver and radar operator seats when in an open position.

k. Manufacture and install a folding chart table approximately 2 x 4 ft on rear cabin bulkhead on centerline of vehicle. Material to be 1/2 in. marine plywood with spar varnish finish.

l. Install one five-man inflatable life raft in suitable fiberglass container. Mount removable container on brackets located on the starboard side of side deck outboard of the deck area and forward of the forward puff port. The raft and container shall be Coast Guard approved.

l. Renew rudder foot pedal restraining straps.

Starboard Pannier:

a. Repair approximately 4 to 6 ft^2 of fiberglass. Remove corrosion on knife edge and renew stop chain on cover door. Remove all corrosion, or renew aluminum vertical angles and repair floor delamination. Replace all missing bolts, rivets, and renew piano hinge on top door.

b. Rotate door to open forward.

Port Pannier:

a. Remove APU in its entirety. Clean and repair approximately 6 ft^2 of fiberglass on pannier. Install new holdown bolts. Seal pannier to provide watertight capability. Install new seals and hinge on top door.

Bottom of Craft:

a. Renew 75 ft of damaged hat sections with Government-furnished new hat sections.

b. Install new fitting for forward port landing pad.

c. Install new plastic seal strip between main beam and side buoyancy tank, port and starboard Frames 7–11.

d. Install and renew all missing, stripped, or rusted bolts in boundary member, aft trunks B.L. 48.

e. Seal all bolt holes, port and starboard sides, where holdown bolts for tripod gun mount backup plates were attached. Fill holes with epoxy material, attach patch plates over holes, and blind rivet using EC-1239 sealant or equal.

f. Clean entire bottom surface of corrosion and paint in accordance with painting specifications.

g. Replace four each deteriorated rubber landing pad base plates.

General:

a. After removal of all wiring, instruments, engine, gearboxes, and electronic equipment, prepare for painting by cleaning the entire craft, interior and exterior, with very high pressure steam to remove all dirt, grease, loose paint and any other foreign debris.

b. Apply a protective finish to all new and replacement parts whether Government furnished or not.

Propeller:

a. Clean rusted spanner nut at base of each blade of propeller.

b. Remove all erosion strips on all propeller blades.

c. Clean all propeller blades of corrosion.

d. Renew rubber boots on leading edge of all propeller blades.

e. Renew rusted clamp and rubber boot covering propeller hub.

Lift Fan:

a. Repair 1/2 in. hole in air intake bellmouth forward, top, port and starboard side.

b. Repair missing fairings, starboard side of nacelle fairing attachments to air intake duct.

c. Remove and renew all aluminum erosion strips on all lift fan blades.

d. Remove fan for inspection.

e. Check and inspect upper and lower bearings.

f. Check nuts on blade to base plate attachment for rust and corrosion and repair as necessary to satisfaction of CG Inspector.

g. Perform a 600-hr maintenance check as outlined in technical publication of this craft.

Engine Area:

a. Remove and repair exhaust extensions.

b. Replace or repair engine oil drain valve and install safety wire.

c. Remove corrosion from fuel filter assembly and renew filter.

d. Clean entire engine bay of all grease, oil and any other foreign material.

e. Remove and replace all rusted hose clamps on all systems.

f. Replace missing seals around exhaust extension top and bottom cowling.

g. Remove engine, replace with Government-furnished engine.

h. Replace Government-furnished generator drive belt.

i. Recondition engine bay fire extinguisher system in its entirety. Renew indicators on port engine cowl.

j. Renew or recharge fire bottles in smothering fire system as needed.

k. Remove, clean, and recondition engine air intake filters.

l. Remove, clean, and replace lube oil cooler.

m. Renew all Government-furnished fuel and lube oil filters.

n. Renew all Government-furnished lube and hydraulic oils.

o. Renew all bolts on forward engine mounts.

p. Reconnect drain lines in bottom of bay for compartment drain.

q. Renew throttle linkage support where needed.

r. Repair 4 in. hole in sheet metal starboard side aft bulkhead 8 in. from bottom of bay.

s. Remove rust on propeller pitch change mechanism and check for proper operation.

t. Replace all bolts on forward flange of shaft between Gearboxes 1 and 2.

Fuel System:

a. Install complete ballast system with Government-furnished tanks, brackets, pumps, and all plastic tubing. Reinstall interconnection between fuel and ballast system.

b. Install two Government-furnished 60-gal removable auxiliary fuel tanks on the port and starboard side decks. Modify the fuel system as follows:

(1) Fabricate and install mounting brackets on port and starboard side deck, each suitable to receive one 60-gal demountable auxiliary fuel tank furnished by the Government. Fit each bracket with holddown straps and secure fittings to prevent movement of the tanks, and withstand upward forces of at least 3.

(2) Position the brackets so as to place the weight of a fuel tank at the longitudinal center of gravity of the craft.

(3) Modify the fuel system to permit transfer of the fuel from each auxiliary tank directly to the main fuel cell. Locate the fuel control valves and switches on the rear cabin bulkhead so as to be operable from inside the cabin. Label all valves and switches for identification.

c. Remove APU fuel components and blank off all tubing or wiring penetrations.

d. Replace missing fuel nozzle grounding receptacle.

e. Calibrate all fuel gages.

Hydraulics:

a. Isolate the hydraulic system for puff ports and skirt lift jacks from the engine lubrication system as follows.

(1) Connect the puff port and skirt lift hydraulic piping to the hydraulic stowage oil tank located on the forsal fin under the radar antenna. The hydraulic pump for this separate system is located on Gearbox 2. The separate system for the puff ports and skirt lift will continue to be operable by the presently installed controls at the operator position.

b. Repair all skirt lift and puff port jacks.

c. Renew all hydraulic hoses and clamps.

Controls:

a. Renew throttle and elevator rubber grips.

b. Renew elevator and rudder fairleads, brackets, and sheaves.

c. Repair and test the following controls for proper movement:

(1) Rudder

(2) Elevator

(3) Throttle

(4) Propeller Pitch

Rear Bag, Port Side:

a. Reattach all loose beeds, bottom inboard.

b. Repair approximately 1-ft^2 hole on bottom outboard side.

Rear Bag, Starboard Side:

a. Reattach all loose beeds.

b. Repair a 1 in. vertical tear.

Keel:

a. Replace the entire missing keel extension.

b. Repair a 6-ft tear aft, starboard side.

Outside Bag:

a. Renew all old type fingers with molded type, approximately 120 fingers.

b. Renew all worn or broken finger chains.

c. Repair tear 2 ft long and 6 in. vertical on skirt forward starboard side Frame 1.

Windshield Wipers:

a. Inspect, clean, and repair or replace all windshield wiper systems to place in good working condition.

b. Inspect, clean, and repair or replace windshield washer system.

Electrical:

a. Change cabin and instrument panel lighting from red to white.

b. Removed all instruments, inspect, calibrate and reinstall. Any instruments requiring replacement will be Government furnished.

c. Disconnect and remove engine speed control switch. Overhaul, remove corrosion, renew defective components, recalibrate, reinstall, and test for proper operation.

d. Make uniform and watertight all vertical fin wiring.

e. Repair broken conduit on port side around lift fan.

f. Remove, overhaul, and reinstall generator.

g. Inspect generator mounting brackets and pulleys; repair as necessary.

h. Remove all present wiring and rewire the entire craft as simply as possible. All wiring to be neatly bundled and hung with plastic hangers. All wiring to be identified and numbered. New wiring diagrams to be provided.

i. Remove main fuse box and install circuit breaker distribution box in its place.

j. Remove all wiring from the following equipment. Plug all holes and make watertight.

(1) Turret Wiring

(2) APU Wiring

(3) APU Fire Detector Wiring

(4) APU Fire Extinguisher Wiring

k. Clean corrosion on connectors in engine compartment and cabin interior.

l. Replace nomenclature on combat ready light.

m. Replace green "stopcock" light.

n. Replace green light switch on instrument panel.

o. Install toggle switch on puff port dump switch.

p. Install new fuel ballast gage.

q. Replace volt ammeter with proper indicator.

r. Replace T5 meter. Meter to be Government furnished.

s. Renew four each ventilating fans in cabin.

t. Renew broken stator vane fuse holder.

Painting and Corrosion:

a. Finish color shall be in accordance with the U. S. Coast Guard Paint and Color Manual, CG-263.

b. Coat all surfaces, interior and exterior after ensuring they are completely free of moisture, soil, dust, grease, and grit. Apply the first coat as soon as possible after craft has been steam cleaned and i dry and when the condition of the ambient air will not allow moisture to condense on the surfaces.

c. Where more than one coat is specified, subsequent coats shall not be applied until the preceding coat has become properly dry and hard. Special care shall be taken that priming coats have dried and hardened properly before applying finish coats or additional primer.

d. Before the application of any coat, feather and touch up all bare spots.

e. Properly protect all fixtures, polished surfaces, valve stems, and gages or instruments during painting; completion of work, remove a paint from glass, plumbing fixtures, and polished surfaces.

f. Touch up any scratched coating of equipment, fixtures, or structure prior to delivery of the ACV.

g. In general, paint all permanently installed piping and cables external to equipment and all hangers, wireway, straps, connection boxes, and junction boxes to match surrounding structure.

h. Do not paint nameplates, cable tags, and warning plates, even where embossed, except those fabricated of aluminum.

i. Do not paint rubber gaskets, hoses and window moldings. All deck fittings shall be painted except those fabricated of aluminum.

j. All plastic surfaces shall be allowed four days to cure before application of paint after repairs.

Visual Identification Markings on ACV:

a. The ACV shall be identified by distinctive visual identification markings consisting of numerals, letters, Coast Guard emblem and diagonal stripes in accordance with the attached drawing. The diagonal stripes are to be painted using Coast Guard No. 40, Coast Guard Blue No. 41, and white alkyd gloss enamel to coincide with the existing type of paint on the boat. Black letters shall be used on white hulls. The official number of the ACV shall be placed on the vertical rudders outboard side at the top and number of the same size just off the main side beams forward port and starboard sides. When necessary, due to size and arrangement of the ACV, deviation in size and location of the markings may be made to achieve pleasing and legible results with the approval of the Coast Guard Inspector. Decals and red and blue enamel will be Government furnished.

Electronics:

a. Remove all electronics equipment and wiring.

b. Install the AN/ARN-75 ADF furnished as GFE, in the following location:

(1) Control unit–above radar operator's position in overhead equipment rack (see photo 1).

(2) Receiver–in equipment bay forward of radar operator.

(3) All wiring and connectors to be supplied by the contractor.

(4) Insulate and install starboard handrail to be used as ADF sense antenna.

(5) ADF homing antenna to be supplied as GFE and will be installed above the cabin by the contractor.

(6) Remove operator's bubble type pitch indicator and install ADF indication (supplied as GFE) in its place.

c. Install Sperry Compass system, furnished as GFE, in the following location:

(1) Place master indicator forward and below its present location in a position easily visible to the radar operator.

(2) Relocate all gyro accessory equipment in the equipment bay forward of radar operator.

d. Install wet compass, furnished as GFE, at operator's station.

e. Install navigation radar, furnished as GFE, at radar operator's position (see photo 2). The radar T/R will be installed on the after cabin bulkhead directly below the antenna mast (see photo 3). Waveguide, antenna, and all interconnecting cables to be supplied as GFE. Install 2 1/2 in. radar mast above new mounting plate described earlier. Install antenna (GFE).

f. Install the integrated communication system, supplied as GFE, as indicated below:

(1) Install radar and operator's master control panel as shown in the enclosed photographs 4 and 5.

(2) Install secondary control panels in the cabin as shown in the enclosed photographs 6 and 7.

(3) All receivers and associated equipment will be provided in its own racking and will be installed against the aft bulkhead, starboard side, photograph 8.

(4) All interconnecting wiring will be furnished as GFE.

(5) All antennas (UHF, VHF(FM), and HF) to be supplied as GFE, and will be installed by the contractor.

(6) HF antenna and antenna coupler to be installed 8 ft forward of present location.

WINTERIZATION

Installation of the simplest and most economical alterations, consistent with safe operation in the Arctic during the projected trials period, was the primary consideration in making the following winterization modifications. It was contemplated that the craft would be operated in the test site area over ice, tundra, and water at temperatures above –30F throughout the trials period.

Descriptions of the winterization modifications are as follows:

Cabin Heater and Window Defrost System:

Two Steward Warner Model 8420 multifuel heaters were installed immediately aft of the seats used by the Radar Navigator and the Craft Operator. Each of these heaters had an output of either 8000 or 20,000 BTU/hr. Thus outputs of 8,000, 16,000, 20,000, 28,000, or 40,000 BTU/hr could be selected in accordance with heating and defrosting requirements. Defrost air was ducted by flexible tubing wrapped in asbestos sheathing from the heaters to the forward windshields, quarter windows, and the door window. Fans located in the ducts from each heater boosted defrost air to the above window. There was no spedific provision for defrosting the remaining cabin windows. Aircraft type padding, attached to the internal side walls and ceiling of the cabin plus a three inch aluminum-Balsa sandwich on the floor, served as cabin insulating material.

Pre-Heating of Engine Compartment:

A procedure was devised for pre-heating the engine compartment, prior to starting the test craft under cold ambient temperatures. Warm cabin air was forced into the engine compartment through a small duct and fan assembly, which was installed to pre-heat the lubricating oil and critical components. Between trial runs at the Arctic test site, heated air was vented over the engine at regular intervals while the test craft was stored in a warm hangar. Time required for pre-heating the engine was thereby significantly reduced.

Plenum Bleed Ducts:

Inlet filters tended to ice up or foul with dirt, water and grass due to the forward facing position of the engine air inlet. Standard plenum bleed ducts of the SR. N5 type were installed on the port and starboard after engine intakes to minimize undesirable ingestions. A vacuum gage was installed between the engine compartment and the ambient air to indicate filter icing or fouling. The original forward facing engine inlet was blocked to preclude the entrance of snow, ice particles and water spray into this critical area.

Metal Panniers:

Aluminum panniers were fabricated to replace the existing fiberglass type, which were worn out. Manually adjustable louvers were installed to allow adjustment of necessary APU cooling air in accordance with the ambient temperature.

Landing Pads:

Without increasing their size, the landing pads were faired with aluminum to a closed-ski type configuration. This modification was made to enhance the prospects of the test vehicle to traverse ice and land surfaces, without entangling the struts and landing pads on protruding obstacles.

Auxiliary Power Unit (APU)

A 60-cycle, 120-volt AC power source for test instrumentation was installed in the rear of the port pannier. This 500-pound unit also had provision to supply power to an emergency test craft battery charger and for emergency hand tools. The battery charger was selected for insertion between the APU and the craft batteries. No drain would be exerted on these batteries due to craft electrical system operation. The APU installed was a standard commercial unit (Onan Model 6.ODJB-IR/90185, 6KW air-cooled Diesel Generator Set). This unit included 21 winterization modifications for Arctic use. Starting and monitoring controls for the APU were located on the port rear cabin bulkhead.

The following accessories were associated with the APU:

a. A 12-volt, 68 ampere-hour Ni-Cd battery was located in the starboard pannier.

b. A Stewart Warner Model 8420 multifuel heater rated at 8000/20000 BTU/hr was installed in the port pannier next to the APU.

c. A fire detection system which consisted of a fusible link detector, activated a light at the operator's station.

d. A dry chemical fire extinguishing system activated by a switch at the operator's station.

The 12-volt APU battery could normally be charged using a small generator on the APU. A separate Exide portable battery charger was provided so that either the 12-volt APU battery or the 24-volt main craft battery could be recharged using output from the APU.

APPENDIX C

MAINTENANCE HISTORY OF TEST CRAFT
(ACY 03, Navy SR-02, Serial 015)

SKIRTS

The skirt system was the section that required the most maintenance during the 1971 Arctic trials. It is especially important to ensure that all flexible air trunks are maintained in good condition because of their function to provide stability to the craft in the cushionborne condition.

More effort was expended on repairing the flexible air bags than on any other area of skirt-associated maintenance. Altogether, 40 percent (159 man-hours) of the total man-hours (401.7) consumed by skirt maintenance were utilized for repairs and replacements of the air bags. Maintenance to hinge attachments and skirt jack chains took 111.2 man-hours, and removal and replacement of fingers on the peripheral trunk consumed another 110.5 man-hours.

During the early part of these trials (April-May), the test craft utilized the runway to transit from the hanger area at the NARL complex where the test craft was housed to the test site on Elson Lagoon. As late winter (May) passed into early summer (early June), this runway became relatively free of its winter blanket and an abrasive material (Duapox Emergency Non-Skid) which had been applied to the runway matting became exposed. After two SEV transits over this abrasive material (10-min operating time), the strakes on the rear bags were observed to be excessively worn. In fact, although they had been exposed to only 50 operating hours, these bags were rendered unserviceable. The abnormally large amount of extra wear was unquestionably attributable to the abrasive material on the runway. Normal operations over the tundra also caused considerable abrasive damage to the rear and the longitudninal keel bags.

Considerable maintenance was performed on bag hinges and hinge lines as well as to skirt lift chains. Chains and hinges are susceptible to deterioration from wear and corrosion. This type of damage could conceivably have been compounded from hovering operations over loose soil, such as that encountered with the Arctic tundra.

The test craft is fitted with a peripheral trunk which has slotted fingers attached at the base through which air is discharged inward under the craft to maintain cushion pressure. Since the condition of the fingers is a significant contributing factor in maintaining correct cushion pressure during craft operations, it is imperative that they be expeditiously replaced when defective. These fingers are subjected to extensive abrasive wear during hovering operations over land and it is required that they be examined subsequent to each such run.

CABIN WINDSHIELD PROBLEMS

The three windshields located on the forward part of the SEV cabin are fitted with windshield wipers and washers. Two heaters were installed on the port and starboard sides aft of the seats occupied by the operator and observer to provide heated air via ducts to the forward windshields, the center door window, and the port and starboard quarter windows. Booster fans are located in each duct and may be operated with or without the heaters by activating the "defroster" switches on the operator's overhead panels.

The heaters were installed to prevent the windshield from fogging during operations in the winter; however, these heaters could not effectively prevent the interior of the cabin windows from clouding up. In fact, at times the fogging (clouding) of the windshield was so bad that the craft operator had to open the door to obtain a clear view. Cracks developed in the center windwhield, possibly by impact with foreign objects from normal operations on the ice and tundra, and it had to be replaced.

ENGINE MAINTENANCE

Although nothing unusual was noted during normal engine operation, there were several successive occasions during rundown when a loud and unusual scraping sound was noted in the turbine section of the engine. This rubbing was thought to originate in the compressor turbine section of the engine, and sounded like main bearing or turbine wear.

During shutdown (after the craft was moved in preparation for changing the engine) the noise was observed to be no longer present. The noise could not be duplicated again, even by conducting several exhaustive run-ups and power checks subsequent to a thorough inspection of both the engine and its components.

To protect the engine, all intake ducts had been fitted with nylon mesh filters to trap the foreign particles embedded in ice spray. Nevertheless engine failure due to ice ingestion had occurred during the CRREL tests at Houghton, Michigan.[31] It was assumed that moisture and melting blown snow on the warm engine behind the filters froze during cold soak after normal craft operation in an environment with large amounts of blown snow. When the craft was started, these chunks of ice broke loose and went through the engine, creating sufficient damage to require engine replacement. Accordingly, an air intake screen was fabricated for installation on the bell mouth of the engine. However, this precaution was discarded at Barrow because analysis of the situation revealed that conditions there would not produce the same hazard. The craft was housed in a relatively warm hanger during the extremely cold periods and when it was parked outside during the warmer periods, blown snow and large amounts of condensed water inside the engine were not present. Since the screen affected engine performance and was considered unnecessary at Barrow, it was not used.

The engine compressor had to be washed periodically with a mixture of clean water and kerosine to remove deposits which could reduce engine power or corrode compressor blades. During the early parts of the test program, it was not possible to wash the engine with fresh water. Moreover, it was found that not washing the engine for extended periods of time did not materially affect engine operation. On occasions when it was observed that the engine continued to lose power, or was subject to high turbine temperatures after routine compressor washings, then a kerosine "soak washing" of the compressor was accomplished. The undesirable effects of salt accumulations was demonstrated during operations on the ice floe in August 1971 by three pops (commencement of stalls) that occurred with the turbine running at 81-83 percent of maximum rpm. Two applications of the kerosine soak eliminated the tendency to stall.

RADAR AND NAVIGATION PROBLEMS

No major problems occurred in this area during the early stages of the program (April through June). However, it should be noted that except for the radar studies conducted by the APL/JHU, there was little or no requirement for this equipment. All navigation, etc. was accomplished by the "seat of the pants," i.e., by looking out the window.

By mid-July, the radar on the test craft was funcitioning intermittently. Several components were replaced, but none of these replacements solved the problem. The nature of the problem was intermittent, and the radar was removed and returned to San Francisco for repair.

A new master indicator was installed after the compass began to show questionable readings in mid-July. After additional trouble, the compass was logged as inoperative; no logical reason could be found for the failure of the system. Further investigation revealed that the master indicator had been installed so as to allow the flex-shaft to part from the adapter. Further troubleshooting revealed that the inverter output voltage of the compass was low. The inverter was changed but no improvement resulted in compass system operation; all components were then removed from the test craft and on 18 August they were shipped to San Francisco for repair.

The only other repair work of any significance was at the end of July when repairs to the ADF were required. After considerable troubleshooting, a broken wire in the antenna connector was discovered and repaired.

COMMUNICATION PROBLEMS

The Coast Guard maintained a guard radio on the marine frequency band for communicating with the test craft during the trial period. Signals were received over the marine band with assurance only up to

ranges on the order of 1 mile. Since the range of the marine band was therefore limited to the area in close proximity to the runway, it was not generally possible for the craft to maintain communications with the shore facility from outlying test sites.

Since all radio frequencies in the Barrow complex were 6 MHz or above, no base radio stations were available to our test craft. A reliable craft-to-shore communications system is considered absolutely necessary for any future SEV Arctic operations.

APPENDIX D
CLIMATOLOGICAL DATA

INTRODUCTION

This section indicates the general climatic conditions recorded in Point Barrow, Alaska (71° 18′ N, 156° 47′ W) between April and 28 August 1981. Weather observations for this report were obtained from the Department of Commerce Weather Station at Barrow, Alaska. Because of the absence of geographic obstructions (terrain, large buildings, etc.), the data taken at Barrow are considered representative of the test area. Test site weather observations were made by means of a portable weather station furnished by CRREL. Notable effects on test vehicle performance attributable to weather factors observed during these trials are found under appropriate headings in other parts of this report.

A general description and summary of average annual weather conditions observed in the Point Barrow area for the years 1931-1970 are available from the Department of Commerce together with official recorded data for daily weather phenomena observed during the interval of our trials.[34]

TYPICAL WEATHER CONDITIONS

The extremes in temperature that characterize the interior regions of Alaska are not found in the Barrow area because moderating influences are provided by the Arctic Ocean and by the lack of any significant natural barriers over the level terrain extending 200 miles southward. Coldest yearly temperatures are generally measured in February (mean of -18.3 F) and there is a significant upward trend beginning in April. A definite transitional period from winter to summer occurs during May. Mean monthly temperature attains a maximum of 39.1 F in July, the warmest month of the year at Barrow. The Arctic Ocean near Point Barrow is normally free of ice in late July and early August. Transition from summer to winter occurs during September.

The sun remains below the horizon between 18 December and 24 January and is continuously visible from 10 May through 2 August. Cloudiness, heavy fog, and precipitation generally occur most frequently in the summer months, during which the sun remains above the horizon. However, the measurable precipitation occurring over a mean of 11 days during October exceeds the mean frequency of 9 or 10 days for the months of July through September. A mean monthly maximum of 0.89 in. of precipitation has

[34] U.S. Department of Commerce Environmental Data Service, "Local Climatological Data – Barrow, Alaska – Annual Summary," Superintendent of Documents, Washington, D.C.

been recorded during the months of July and August, and a mean minimum of 0.14 in. was recorded for May between 1931 and 1970. Over this 40-year period, more than 1 in. of snowfall was recorded as follows:

Month	Frequency in 40 Years
April	23
May	22
June	5
July	7
August	9

Winds are predominately easterly with an average speed of about 12 knots. The windiest months are during the fall. Only small variations in mean wind speed occur throughout the year. Strong winds in excess of 50 knots have been recorded during every month of the year.

ACTUAL WEATHER CONDITIONS 1 APRIL – 1 SEP 1971

Table D-1 shows the maximum, minimum, average maximum, and average minimum temperatures observed from April through August 1971.

TABLE D-1 – TEMPERATURE DATA EXTRACTED FROM 1971 OBSERVATIONS
(Data are given in degrees F)

	April	May	June	July	August
Maximum	18	34	57	63	60
Minimum	–24	–6	25	30	25
Max. Avg.	1.2	21.7	39.0	46.0	36.7
Min. Avg.	–10.2	13.0	31.1	34.7	30.3
Monthly Avg.	– 4.5	17.4	35.1	40.4	33.5

Monthly totals and frequency of snowfall are shown in Table D-2 below, together with the dates of maximum occurrence and ground accumulations.

TABLE D-2 – ACCUMULATION AND FREQUENCY OF SNOW DURING THE 1971 TRIALS
(Accumulation values are in inches)

	Monthly Total Snowfall	24-Hr Max. Snowfall	No. Days Measurable Snow	No. Days Traces of Snow	Max./Ground Accumulation*
April	0.2	0.2	1	22	30/10
May	2.4	1.0	8	19	10/10
June	0.2	0.2	1	6	3/5
July	0.0	–	0	5	29/Trace
August	2.4	1.4	2	17	21/2
Five-Month Total	5.2		12	69	

*Date/depth (inches).

Note that during the 5-month trial period, 3.4 of the total of 5.2 in. fell on three of the 12 days of measurable snowfall.

Drizzle totaling less than 0.01 in. was recorded on May 31. Rain and drizzle amounting to 0.12 in. fell during 6 days in June. Measurable rain and drizzle accumulating to 0.98 in. was observed during 8 days in July. Measurable rain or drizzle totaling 0.06 in. fell during 4 days and traces were recorded on 17 days during August.

Maximum and average recorded winds and their direction or origin are shown in Table D-3 for the period of the 1971 trials.

TABLE D-3 – RECORDED WIND VELOCITIES DURING THE 1971 TRIALS

	Max. Wind Speed mph	Wind Direction deg	Average Wind Speed mph	Wind Direction deg
April	30	60	11.2	50
May	25	60	10.7	70
June	29	70	12.4	70
July	30	210	11.8	70
August	23	60	10.7	350

CONCLUSION

It was concluded that the climatological data observed during the 1971 Arctic trials were in accordance with the normal pattern in the area between the months of April and September.

APPENDIX E

DAILY TEST LOG OF 1971 ARCTIC TRIALS

Day	April	May	June	July	August
1	First Flight at Barrow	SEV Down for Side-Body	Skirt Drag Tests	SEV Inoperative	SEV 100-Hour Overhaul
2	Terrain Run	Repairs	Turning Tests	Tow to Beach	
3	Ryan Radar Installed		Directional Stability	Return to Hangar	
4	Accident on Ice				
5		SEV Down for Side-Body			
6		Repairs	Directional Stability	Return to Hangar	SEV 100-Hour Overhaul
7	Accident on Ice	SEV Operational	Obstacle Tests	Prop Cable Repaired	Univ of Washington Marginal
8	Instrumentation Checkout	SEV Operational	Obstacle Tests	Terrain Run, Training	Ice Zone Experiments
9		SEV Operational	Snow Obstacle Test	Terrain Run, Training	
10		Ryan Radar Checked OK	Snow Obstacle Test	Thrust Tests	
11		Ryan Radar Failed	Ryan Radar Test		
12		Instrumentation Checkout	Obstacle Tests		
13		Instrumentation Checkout		Thrust Tests	
14	Instrumentation Checkout	Newell Recorder Installed		Obstacle Tests	Univ of Washington Marginal
15	SEV Down for Side-Body	Newell Recorder Installed		Obstacle Tests	Ice Zone Experiments
16	Repairs	SEV to Point Barrow for		Terrain Run	Reinstall & Check Out of Instru-
17		Radar			mentation by NSRDC Personnel
18		Tests			
19		Laser Installed			Reinstall & Check Out of Instru-
20		SEV to Point Barrow for	Obstacle Tests	Terrain Run	mentation by NSRDC Personnel
21		Radar & Laser Tests	Terrain Run	CRREL Tundra Tests	CRREL Dry Summer
22		Radar & Laser Equipment	Terrain Run	Turning Tests	Terrain Tests & NSRDC Stability,
23		Removed from SEV	Terrain Run	Obstacle Tests	Control & Maneuvering on
24			Prop Cable Damaged	Obstacle Tests	Dry Tundra Tests
25				Instrumentation Removed	Final Ryan Radar Tests
26		Radar & Laser Equipment	Prop Cable Damaged	Instrumentation Removed	
27		Removed from SEV	SEV inoperative	SEV 100-Hour Overhaul	
28		Static Load Tests			
29	SEV Down for Side-Body				Disassemble, Pack up & Prepare
30	Repairs		SEV Inoperative		for Shipment to
31		Static Load Tests		SEV 100-Hour Overhaul	Next Base

APPENDIX F

EVALUATICN OF DOPPLER VELOCITY SENSOR

The primary function of the doppler velocity sensor was to provide forward and drift velocity information, with special emphasis on the construction for Arctic environment. The velocity sensor (two-beam continuous-wave doppler radar system) was mounted aft near the centerline of the SEV to minimize backscatter effects due to craft motions and terrain differences.

The initial installation was at San Francisco in mid-March 1971. The tight test schedule together with operational difficulties (defective 400-Hz source, high voltage power supply failure, and a faulty Klystron) precluded calibration and acceptance of the sensor, and it was returned to the vendor for repair.

The sensor was reinstalled on the test craft at NARL in early April but failed to operate properly during a short checkout period. Again, the failure was due to two faulty power supplies (high voltage power supply transformer and an exploded capacitor). After their repair, the sensor was reinstalled and operated successfully over snow and ice on 10 May 1971. Subsequent attempts to use the velocity sensor were unsuccessful; freezing spray iced the antenna exposed cables and connections. The velocity sensor was returned to the vendor for rework.

The next operational attempt ended on 22 June 1971. Power supply damage was found but the cause of failure was not known, and once again the radar set was returned to the vendor.

During the final attempt in early August, the antenna was installed on the bow of the test craft. In this position, the radar functioned properly when the craft was over water but only intermittently when the test craft was over tundra. Again, the failure appeared to be in the high voltage power supply and/or the Klystron.

From the initial time (March 1971) that development effort began on the doppler velocity sensor until all testing was terminated (mid-August 1971), all its subsystems operated as designed when on the bench, but (except for the one day) they did not perform satisfactorily once installed on the test craft.

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13. ABSTRACT

A test program for a 10-ton gross weight surface effect vehicle (SEV) was devised to document operating experience in the Arctic, to identify generic problems including limitations of SEV operation, to acquire engineering data for navigational and communication subsystems, and to evaluate environmental and ecological aspects of SEV operation. This report presents sample quantitative and qualitative results of the various tests conducted at Alameda Naval Air Station, California, and the Naval Arctic Research Laboratory at Point Barrow, Alaska, between 1 February and 28 August 1971. Detailed technical discussions are contained in cited references. An operational log and maintenance history are also presented along with pertinent observation and comments.

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